Volume XL December 1945 Number 8

Economic Geology

and the

Bulletin of the Society of Economic Geologists

CONTENTS

The Hardrock "Porphyry" of Little Long Lac ..... *J. A. Reid* 509

Petrographic Analysis by Fragment Counting ..... *Felix Chayes* 517

Notes on the Derivatives of the Triassic Diabases of Pennsylvania ... *W. Harold Tomlinson* 526

The Fineness of Gold, with Special Reference to the Morobe Goldfield, New Guinea, Part II ..... *N. H. Fisher* 537

Editorial:

New International Mineral Problems ..... *Alan M. Bateman* 564

War and Postwar changes in this Journal ..... *The Editor* 566

Discussion and Communications:

Minor Elements in Sphalerites from Belgium ..... *Pierre Evrard* 568

Reviews:

Fortress Islands of the Pacific—Their Geography and Strategic Importance (Hobbs) ..... *Ralph E. Digman* 575

Minerals of Might (Hotchkiss) 575

Coasts, Waves, and Weather for Navigators (Stewart) 576

Electronic Equipment and Accessories (Walker) 576

Books Received ..... *Ralph E. Digman* 577

Society of Economic Geologists

Program for Twenty-sixth Annual Meeting 579

Scientific Notes and News 612

PUBLISHED SEMI-QUARTERLY

Five Dollars a Year, One Dollar a Copy

THE ECONOMIC GEOLOGY PUBLISHING COMPANY

Printed by Lancaster Press, Inc., Prince and Lemon Streets, Lancaster, Pa.

Entered as second-class matter, March 30, 1906, at the Post Office at Lancaster, Pa., under the Act of Congress of March 3, 1879

Economic Geology

and the

Bulletin of the Society of Economic Geologists

Issued Semi-Quarterly and sent to subscribers on or about the following dates: February 1, March 15, May 1, June 15, August 1, September 15, November 1, December 15.

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Foreign Agents. Geo. Allen and Unwin, Ltd., No. 40 Museum St., London, W. C. 1, **British Agents.**

Indexed in the Industrial Art Series.

LANCASTER PRESS, INC., LANCASTER, PA.

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AND THE

BULLETIN OF THE SOCIETY OF ECONOMIC GEOLOGISTS

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ECONOMIC GEOLOGY

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ECONOMIC GEOLOGISTS

VOL. XL DECEMBER, 1945 No. 8

THE HARDROCK "PORPHYRY" OF LITTLE LONG LAC.

J. A. REID.

ABSTRACT.

The Hardrock "porphyry" of the Little Long Lac gold mining district of northwestern Ontario is a rock of considerable economic interest in that area, as some of the ore deposits worked in two of the leading mines —the Hardrock and the MacLeod Cockshutt—are definitely connected with it. It is of puzzling and anomalous character and diverse opinions have been held at different times as to its nature and origin. The writer, however, as the result of recent studies, has come to the conclusion that it is an arkose and part of the general assemblage of sedimentary rocks of the district.

INTRODUCTION.

DURING the past fifteen years the Little Long Lac area has been the major gold producer of the new mining districts of Northwestern Ontario. It is situated in the northeastern part of the Thunder Bay Mining Division, 177 miles by rail northeast of Port Arthur, Ontario, 60 to 65 miles north of Lake Superior, and is accessible either by rail or by the Trans Canada highway from all important centers either east or west.

According to E. L. Bruce,[1] the area is on the dragfolded north limb of a large syncline consisting mainly of sedimentary rocks of Temiskaming age, with a minor amount of acid and basic intrusives, infolded in Keewatin greenstones which have unconformable relations to the sediments.

The sediments comprise greywacke, arkose, iron formation, impure quartzite and conglomerate, and the associated intrusives consist of acid porphyries, diorite, diorite porphyry and diabase. With the exception of the diabase, all of these formations (seen by the writer) have conformable relations, are involved in the folding, and are more or less schistose. The strike is approximately east west, and the dip, where not affected by drag folding, 60 degrees and upwards to the south. The main syncline and the associated drag folds pitch 27 to 30 degrees west. Bruce [2] regards the porphyries and

[1] Bruce, E. L.: Little Long Lac Gold Area. Ont. Dept. of Mines, Vol. XLIV, Part III, 1935, pp. 10–25.

[2] Bruce, E. L.: op. cit., p. 10.

diorite as post Temiskaming. The diabase he tentatively classifies as Keweenawan.

The diabase is the latest rock in the area, it is unsheared, and consists of dikes cutting all the other formations including the orebodies. These dikes, which vary from a few inches to 40 or more feet in width, all have a northerly strike and easterly dip. They are particularly numerous in the workings of the Hardrock mine.

Some faulting has been noticed in the area in connection with the working of the mines. Its general significance, however, is unimportant.

All the orebodies in the mines mentioned by the writer are definitely connected with dragfolding of the associated rocks.

A rock known as the Hardrock "porphyry" is of considerable interest in the district, as the discovery of gold in a vein in it by Mr. W. W. Smith in 1931 on the property of the Hardrock Gold Mines first attracted public attention to the area, and since that time, veins, in or adjacent to this formation, have proved to be a minor but important source of ore to the Hardrock and MacLeod Cockshutt mines.

The rock gets its name from the fact that it was first found, and has the largest surface outcrop on the Hardrock property, but it is also very prominent both on the surface and underground in the MacLeod Cockshutt mine, which adjoins the former to the west. The rock is of enigmatic character and varying opinions as to its nature and origin have been held at different times. At first, from its appearance, it was thought to be an intrusive porphyry, then, as it was seen that it always had conformable relations with the adjoining sedimentary rocks, opinions veered to consider it an altered and recrystallized arkose. This second notion held sway until E. L. Bruce made his first report on the region and in it he decided, mainly or entirely on microscopic evidence, that it is an albite porphyry of intrusive origin; this conception at first was not generally accepted locally, and a hybrid term "porkose" (compounded of porphyry and arkose) was coined to designate the rock. In the course of time, however, opposition to Bruce's idea died out and the rock is now generally accepted as "porphyry."

Since the date of Bruce's second report [3] a great deal of work has been done in the Hardrock and MacLeod Cockshutt mines, and the "porphyry" has been accurately mapped underground by the geological staffs of the respective properties. In 1943 and 1944, the writer was engaged to make rather exhaustive reports on these two mines, and as a result of his studies came to the conclusion that, in spite of its apparent porphyritic texture, the rock is most probably neither intrusive nor igneous.

DESCRIPTION.

In appearance the Hardrock "porphyry" is a fine textured schistose rock, pale gray to nearly white in color, with frequently a slight yellowish cast. The larger feldspar individuals or "phenocrysts" are often inconspicuous

[3] Bruce, E. L.: New developments in the Little Long Lac Area. Ont. Dept. of Mines, Vol. XLV, Part II, 1937, pp. 118–149.

megascopically, but are readily discernible in thin section. It carries 1 to 1½ per cent evenly disseminated fine pyrite together with abundant stringers and small veinlets of quartz which not infrequently carry small values in gold. In places where definite shear zones cut the "porphyry," the quartz increases sufficiently in quantity and value to form workable orebodies, but in most cases the payable veins are in the sediments either close to or adjoining the contacts or off bends or "elbows" in the "porphyry." On casual inspection, the "porphyry" shows rather sharp contacts against the adjoining rocks but in every instance close investigation will show a transition zone a few inches in width, where the light colored "porphyry" blends into the dark sediment, greywacke or iron formation.

CHEMICAL AND MINERALOGICAL COMPOSITION.

Dr. Bruce in his first report gives a chemical analysis of the rock and its calculated mineralogical composition together with a brief petrographic description. The analysis "A" and mineralogical composition "C" are shown in the table below in which is also included, for purpose of comparison, the analysis, "B," of a rock of known sedimentary origin, *i.e.* the greywacke matrix of a boulder conglomerate from Thompson Township, Ontario.

	"A" Percentage	"B" Percentage	"C"	
			Mineral	Percentage
SiO_2	62.36	61.96	Albite (about $Ab_{97}An_3$)	47.40
Al_2O_3	17.52	17.20	Quartz	20.70
Fe_2O_3	.69	1.42	Sericite	14.53
FeO	.62	4.49	Carbonate $(CaMgFe)CO_3$	7.94
CaO	3.78	1.00	Kaolin	7.08
MgO	1.15	3.27	Pyrite	1.20
Na_2O	5.46	5.27	Limonite	.82
K_2O	1.70	2.04	Ilmenite	.62
TiO_2	.33	.60	Apatite	.25
P_2O_5	.06	—		
MnO	—	.10		
H_2O (110 degrees)	1.04	.10		
H_2O (above 110)		2.70		
CO_2	4.15	—		
FeS_2	1.20	—		
Totals	100.06	100.15		100.54

"A": Bruce, E. L.: Little Long Lac Gold Area. Ont. Dept. of Mines, Vol. XLIV, Part III, 1935, p. 21.
"B": Collins, W. H.: The Onaping Map Area. Mem. 95, Geol. Surv. Can., 1917, p. 65.
"C": Bruce, E. L.: Little Long Lac Gold Area. Ont. Dept. of Mines, Vol. XLIV, Part III, 1935, p. 22.

In his description of the rock Bruce [4] states: "In the hand specimen the rock resembles a quartzite, but in thin section it is easily recognized as a porphyry. The phenocrysts are albite with a few rounded grains of quartz. The feldspars are well formed but some of them are fractured. The ground

[4] Bruce, E. L.: op. cit., p. 23.

mass is composed of quartz and feldspar. Sericite, calcite and a little chlorite are present."

The writer examined microscopically nine thin sections taken from the first (150 foot) level of the Hardrock mine. Of these, Nos. 1, 2, 5, 6, 7 and 9 were taken of what definitely appeared to be "porphyry"; Nos. 4 and 8 of greywacke near the "porphyry" contact. No. 3 was doubtfully credited to "porphyry" and No. 4 to greywacke.

All the thin sections show considerable hydrothermal alteration especially in the ground mass. Sericite is the most conspicuous secondary mineral, but there is also considerable carbonate, and introduced quartz. The carbonate not infrequently shows a faint pleochroism in shades of grey, indicating the presence of some iron. Secondary quartz in part is in the form of veinlets and also as an enlargement of original grains of this mineral. All the larger quartz individuals have rounded outlines, but ragged edges, which when investigated are seen to consist of tiny tongue-like protrusions invading the adjoining ground mass. They also in places seem to have engulfed parts of the ground mass. The sericite-carbonate alteration appears to have attacked indifferently both the "porphyry" and the greywacke and if anything the amount of this alteration is greater in the latter rock. Pyrite, frequently showing crystal form, occurs sparsely in the slides.

Apart from the secondary minerals above noted, the "porphyry" consists of relatively large feldspar and quartz individuals in a much finer grained ground mass of feldspar and quartz. The feldspar "phenocrysts" are mainly or entirely plagioclase and, as Bruce states, consist of albite (the maximum extinction angle normal to 010 being —20 degrees). The larger feldspars appear to be original in the rock, a few are fairly clear but most are more or less turbid, having suffered the same kind of alteration as the ground mass, but in somewhat less degree. A few have fairly good crystal form but most have a rounded or broken appearance extremely suggestive of detrital origin. It might be suggested that this apparently fragmental appearance is autoclastic and due to the crushing of the rock consequent on folding. On that score, however, there is little evidence; only exceptionally are the larger feldspars accompanied by mylonitic trains, some of them show fracturing as a result of the folding stresses, but most of the larger individuals which show no sign of subsequent fracturing have a definitely clastic outline. Under the microscope the rock shows not infrequently a rude banding which generally characterizes the ground mass and the middle sized feldspar fragments, and not usually the larger ones.

A feature of the rock is the practical absence of mafic constituents; only one speck of chlorite was seen in all the "porphyry" slides examined. Rutile, both in the form of small crystals and fragments scattered throughout the rock, is moderately abundant. In places it occurs as "nests" or clusters which seem residual after some previously existing titaniferous mineral such as ilmenite.

The greywacke thin sections all show a definite banding and the feldspars are considerably smaller than those in the "porphyry." The most distinctive feature of this rock which differentiates it from the other is chlorite, which is

present in large amount and practically absent in the "porphyry." Rutile also is more plentiful in the greywacke.

STRUCTURE.

The shape of the "porphyry" is well shown in Figure 1, which is its outline as mapped on the 250 foot level of the Hardrock Mine and the corresponding horizon of the MacLeod Cockshutt. As can be seen it is intensely folded, having been doubled back on itself no less than four times. On the

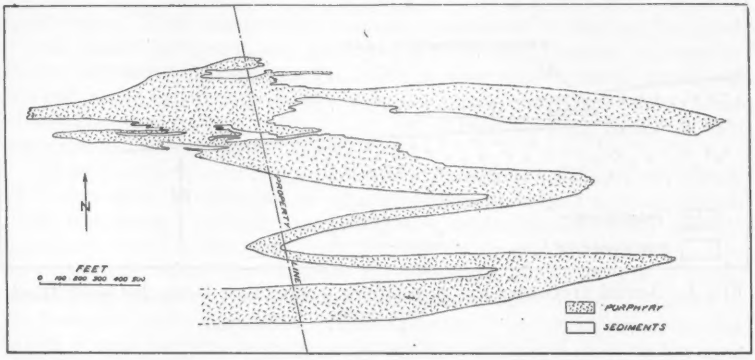


FIG. 1. Plan of the Hardrock porphyry on the second (250 foot) levels. Hardrock and MacLeod Cockshutt mines.

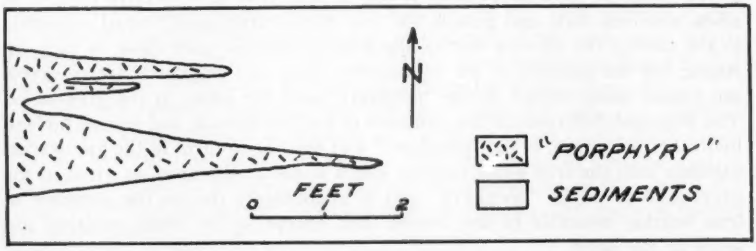


FIG. 2. Inter-fingering of porphyry and greywacke. Back of East Drift, 2nd level, Hardrock mine.

plan it has a maximum length of 3,450 feet and a width (including the space between the folds) of 1,300 feet. At the south side an unmapped projection extends an unknown distance westward across the MacLeod Cockshutt and into the Mosher Long Lac property. To the writer's knowledge, it is entirely conformable with the inclosing rocks and agrees with them in strike, dip and pitch. From Figure 1, it is to be noted that at the ends and along bends the "porphyry" has finger-like projections into the adjacent rock; this

is a very characteristic feature and can be frequently observed underground. It is shown in detail in Figure 2 and Figure 3. These finger-like projections extend along the bedding planes of the sediments without crossing them or disturbing their orientation. In Figure 3 can be seen a sliver of banded greywacke about a foot long and an inch wide entirely inclosed in a "porphyry" tongue with the banding still holding its original alignment. In no case did the writer ever see the "porphyry" directly transgressing the bedding planes of the sediments; it merely seems to dovetail into them along the strike.

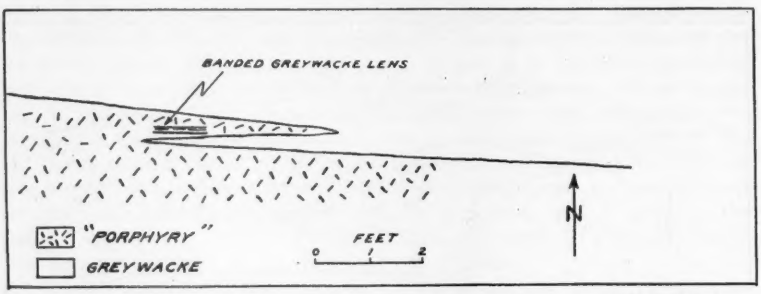


FIG. 3. Banded greywacke lens in porphyry tongue, East Drift, 2nd level, Hard-rock mine.

SUMMARY.

If consideration be given to the two analyses quoted, "A" of the "porphyry" and "B" of a greywacke, it can be seen that in respect to content of silica, alumina, soda and potash, the two rocks carry nearly equal amounts; in the case of the alkaline earths, the total content is quite close in each instance, but the quantity of the components, lime and magnesia, are reversed, the former being higher in the "porphyry" and the latter in the greywacke. The principal difference is the presence of carbon dioxide and pyrite, both of hydrothermal origin, in the "porphyry" and absence of them in the greywacke, together with the iron oxide content which is about 4½ times as great in the greywacke as in the "porphyry" and is undoubtedly due to the presence of iron bearing minerals in the former and, except pyrite, their practical absence in the latter.

To sum up the matter, it would appear that analysis "A" could very well be of a sandstone or arkose with a high percentage of feldspar and hence could indicate a rock of clastic origin.

In regard to the calculated mineral composition, as 99 per cent of it comprises minerals, including albite [5] which could be probably or positively of secondary or hydrothermal origin, it throws little light on the original nature of the rock. Titanium dioxide in the analysis is calculated to ilmenite in the mineral composition. No ilmenite was definitely identified in any of the

[5] Lindgren, W.: Mineral deposits. 4th Edition, 1933, pp. 661–680.

slides but sufficient rutile was found to account for all the titanic oxide shown in the analysis. This mineral, however, is common both in sediments and altered igneous rocks, in the latter case resulting from the breakdown of ilmenite or other titanium bearing minerals and is therefore of slight diagnostic importance; the same is also true of apatite, a resistant mineral, which is found both in igneous rocks and in detrital deposits resulting from their decomposition.

Petrographic examination of the rock shows that the larger feldspar individuals which give the rock its porphyritic appearance are undoubtedly original as they have been affected by the same sort of alteration as the other constituents. Their clastic origin, however, is indicated by the fact that good crystal form is infrequent, and that most of them have rounded or irregular shapes, suggestive of fragmentation, which in most cases seems to be original and not caused by stresses consequent on the folding of the rock body. Most of the thin sections also show a rude but definite banding, which is also indicative of a sedimentary origin.

In its structural relations the Hardrock "porphyry" follows and reflects all the intricacies of folding in the adjacent sedimentaries and as far as known never transgresses geologic boundaries; now while intrusive rocks are frequently governed in their occurrence by pre-existing geologic structures, they rarely or never follow them entirely, but frequently take short cuts by crossing bedding planes or other barriers; this feature, however, seems absent in the formation under discussion. If the "porphyry" be considered of igneous origin, it must therefore be either an intercalated volcanic flow or an intrusive sheet or sill which invaded the sediments previous to the period of folding. This, however, is negatived, or at least rendered improbable, by the irregularities in the northern part of the rock body, and by the long finger-like extensions which particularly characterize that part of it. This feature, it may be mentioned, is especially characteristic of the ends of the rock mass, which is where it might be expected to be, and can be most readily explained by the dovetailing of sediments of different composition by original deposition.

The color contrast between the "porphyry" and the adjoining rocks is mainly due to the natural light color of the former rock, intensified somewhat by hydrothermal alteration as the introduced minerals, sericite, quartz and carbonate, are all white or pale in color; the greywacke on the other hand contains considerable chlorite and is dark grey or green, and the iron formation nearly black.

In conclusion, from consideration of the above lines of evidence, chemical, petrographical and structural, it appears reasonably certain that the Hardrock "porphyry" is of fragmental origin, and is a hydrothermally altered arkose belonging to the general assemblage of sedimentary rocks of the area and that its apparent porphyritic texture is due to imperfect settling or sorting conditions prevailing at the time of original deposition.

It is probable, however, that the name "porphyry" will continue to be applied to this rock, both from usage, and as a convenient field term to distinguish it from the others, especially as it is definitely connected with part of the ore deposition.

ACKNOWLEDGMENT.

The writer herewith expresses his appreciation of the aid given him in the collection of material and data by Messrs. M. S. Stevens, A. R. Matheson and G. P. Wigle, respectively chief engineer, geologist and mine superintendent of the Hardrock Mines, Ltd. The plan (Fig. 1) which accompanies this article is the work of Mr. Matheson. He is also indebted to Dr. M. H. Frohberg of the Macassa mines, Mr. A. W. Johnston of the Conwest Exploration Company, and Professor A. MacLean of the University of Toronto for assistance in the examination of the thin sections, and discussion of the same.

TORONTO, ONTARIO,
May 15, 1945.

PETROGRAPHIC ANALYSIS BY FRAGMENT COUNTING.[1]

FELIX CHAYES.[2]

II. PRECISION OF MICRO-SAMPLING AND THE COMBINED ERROR OP SAMPLING AND COUNTING.[3]

ABSTRACT.

The technique of micro-sampling is described. Experimental analyses of standard mixtures are used for the development of an empirical equation expressing combined error of sampling and counting as a function of composition and count length. The known error of counting is extracted from this combined error, yielding a statement of micro-sampling error independent of count length. Application of this sampling error to any known counting error is described. Accuracy of the method is indicated by comparison of number frequency and weight values for the same standard samples. Further developments of the investigation are suggested.

INTRODUCTION.

In the present report the results of a previous investigation of counting error (1) are used as a means of determining the error of micro-sampling. The micro-sampling procedure is described in detail. The results of duplicate analyses on several of the standards used in the counting-error study are used to derive an empirical equation exhibiting total sampling and counting error as a function of composition level and count length. From this equation and the previously determined values for counting error alone, an equation relating micro-sampling error to composition is derived. This relationship is independent of count length. Values for counting error for a wide range of count lengths can be obtained graphically from Fig. 4 of the previous paper, reproduced here as Fig. 1. By the usual treatment of additive errors, any of these values may be combined with the properly chosen value of sampling error as read from Fig. 2, below. The result is the probable error of sampling and counting in a single analysis made by the sampling procedure described in this paper and the intersection method of counting described in the previous report.

Although the results apply strictly only to 100- to 200-mesh sand grains, they indicate clearly that the precision of number frequencies determined by fragment counting is considerably greater than most petrographers would have suspected.

The accuracy of the method will be a function of the shapes and specific gravities of the constituents of the mixtures being analyzed, and except with extremely acicular or platy minerals (and possibly strongly magnetic ones as

[1] Published by permission of the Director, Bureau of Mines, U. S. Dept. of the Interior.
[2] Petrographer, Eastern Experiment Station, Bureau of Mines.
[3] Part I: Econ. Geol., vol. 39, 1944, p. 484.

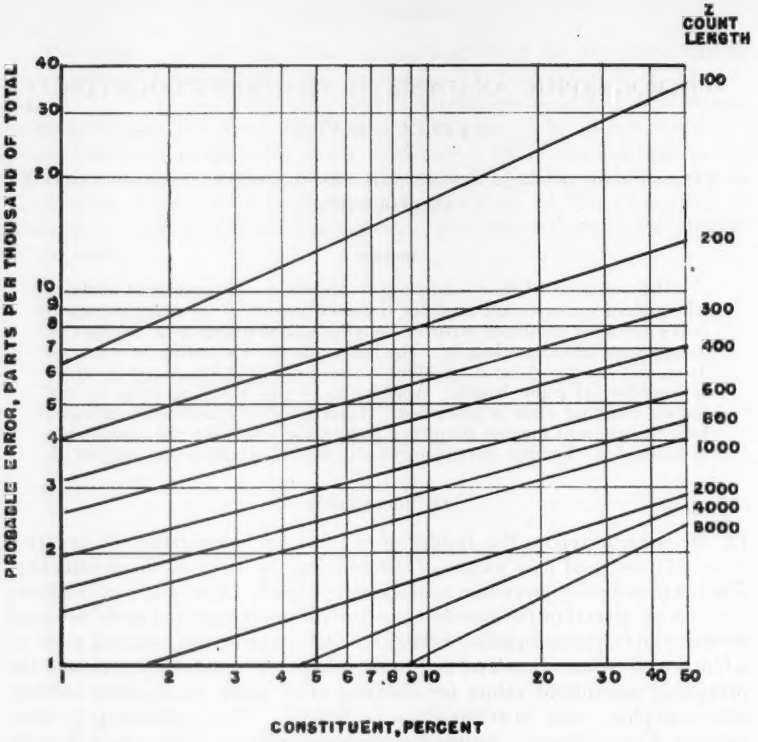


FIG. 1 — VARIATION OF COUNTING ERROR WITH COUNT LENGTH

well) the effect of these will be confined largely or entirely to the count. It should be a relatively simple matter, therefore, to develop empirical "shape-factor" corrections. The potential accuracy of the method with mixtures requiring neither shape nor gravity corrections is indicated in Table 2, below. There is apparently no systematic divergence between the mean values of the number-frequency estimates and the percentage compositions determined by weighing.

MICRO-SAMPLING TECHNIQUE.

Previous studies of micro-sampling technique are summarized by Krumbein and Pettijohn (2). The development of a microsplit of the Jones-sampler type is due to G. H. Otto (3), though the very similar device used for the work reported below was not built exactly according to his design. Otto made no attempt at a formal discrimination between counting and sam-

pling errors, and to the writer's knowledge the present report is the first published notice of such a study.

Until the beginning of the war, the Eastern Experiment Station petrographic laboratory had not been called on for more than occasional quantitative analyses of minor constituents. The need for large numbers of such analyses developed abruptly and with little warning, so that there was no opportunity for the systematic development of micro-sampling technique. In response to the new demand, it was a very simple matter to extend the length of count and improve the distribution of traverses. But these improvements applied solely to the counting step and it was felt that the only sampling procedure then in use—the normal spatula sampling of petrography—was not adequate for the new task. A micro-sampler was constructed according to plans available in the literature (4), and pressed into service. Between 1942 and the spring of 1945 this sampler has been in constant use, and the technique described and calibrated below is that which was developed in practice. The statement of error applies strictly only to this procedure as used on 100–200 mesh grains.

Abundant experience indicates that the sampling error does not vary widely for a considerable range of size both above and below the 100–200 interval, though quantitative analysis of the error for other size grades and ranges has not yet been undertaken. It is probable also that minor variations in technique may be introduced without requiring serious revision of the error formula, though this again is a matter concerning which no systematic study has yet been made.

The sampler is essentially a miniature Jones splitter. The published plans also include a rather flat, long-handled "scoop," but on the first day of operation this was abandoned in favor of a piece of ordinary 3″ × 5″ note paper, one end of which is creased at the center. Cardboard specimen trays (2″ × 1½″ × ⅝″) are used as receiving boxes. The trays and note paper are replaced as they become worn. In routine work, the sampler is cleaned with a blast of compressed air or by tapping. If the bolts which hold it together are loosened before the tapping and compressed air treatment, and then carefully (hand) tightened and kept tight during operation, nearly all the grains which have not been dislodged by the cleaning will be held firmly in place. From time to time the instrument should be completely disassembled and carefully wiped. (This thorough cleaning contributes immeasurably to the confidence of the operator, but probably has very small effect on the precision of the result.)

The sampling procedure is as follows: Ten grams or less of the sized sand are poured into a cone-shaped mound on the note paper. The *uncreased* end of the note paper is curved into a U-shaped trough and the paper is held so that the edge of this trough is at the center of the sampler. The material is slowly poured through the sampler, which may be shaken gently from time to time. One of the receiving boxes is emptied onto the note paper and the process is repeated. When the sample has been reduced to a half gram or less the *creased* end of the note paper is used, and the V-shaped trough so formed is passed back and forth across the width of the sampler during the

pouring. It will always be found convenient to empty the receiving box near whichever end of the note paper is to be used for the pouring, rather than in the center. After each pass the sampler is tapped to free it of trapped grains, the empty note paper is flicked or shaken, and the empty receiver box is inverted and tapped a few times with the same purpose. These precautions are taken to insure that the final sample will consist of material that has been systematically passed through the sampler rather than of grains that have caught on the paper or box. As the sample becomes smaller, it is necessary to gather it together near the creased end of the paper before pouring. This is conveniently done by pinching the crease shut with thumb and forefinger

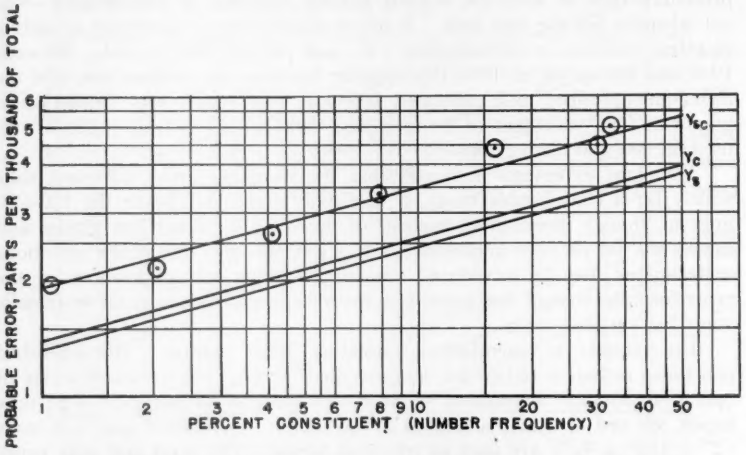


FIG. 2– SAMPLING AND COUNTING ERRORS. Y_s = SAMPLING ERROR; Y_c = COUNTING ERROR; Y_{sc} = COMBINED COUNTING AND SAMPLING ERROR, COUNT LENGTH 1000 GRAINS. ⊙ = EXPERIMENTAL DATA.

of one hand and tapping the other end of the paper with the forefinger of the other hand. The last three passes are the most critical, for too many grains insure a poor count and too few grains yield a poor sample.

To date, no measurement of volume or weight of the final sample has been introduced into the process, though this would probably be a useful innovation if it could be accomplished without too much lost time. For 100- to 200-mesh sands of 2.6–2.8 specific gravity the final count should weigh between 5 and 10 milligrams. With a little experience, one can easily judge whether the sample is of the proper size without having the slightest idea of its true weight or volume. The average of twenty separate samples cut without reference to each other in one experimental run was 8 milligrams. Quantities smaller than this cannot be handled conveniently with the paper scoop. Larger quantities must be used for coarser sands.

Two or three generous drops of the desired index oil are placed on a clean glass slide. The sample is carefully poured into the center of the pool of oil;

oil and sample are mixed thoroughly with a clean glass rod, a cover slip is put on in the usual fashion and the slide is mounted in the mechanical stage.

The entire procedure should not take more than three minutes, and if the initial sample is less than 10 grams the time will be proportionately less. Since the time consumed in counting will be appreciably greater (8 to 15 minutes for a single 1000-grain count of readily identifiable fragments) it is wise to inspect the slide quickly and discard it if it is too lightly or too heavily populated. No extension of the count-length can correct sampling errors, and if a slide is too heavily populated for a short count, the chances are that a longer count will not be much better.

TOTAL ERROR OF COUNTING AND SAMPLING.

On each of the beryl-feldspar standards used for the counting error study a number of duplicate analyses were made, each analysis consisting of reduction of the total sample (about 10 grams) by microsampling, followed by a single 1000-grain count on the final cut in a 1.558 oil. Table 1, below, gives the results of the analyses.

TABLE 1.

% Beryl (mean of all analyses)	Probable Error of Single Analysis (in parts per thousand)	Number of Analyses
1.06	1.95	15
2.06	2.13	16
4.09	2.66	15
7.86	3.34	20
16.06	4.48	20
29.97	4.47	10
32.52	5.07	15

A least mean squares solution for probable error as a function of composition gave:

$$Y_{c+s} = 1.91\, x^{0.267}. \qquad (1)$$

The experimental data and a graph of equation (1) are plotted in Fig. 2.

ERROR OF SAMPLING.

The sampling error is clearly independent of the counting process, and if microsplitting is continued until the final sample is of satisfactory size, the counting error will be independent of the sampling process. (Large and erratic variations in the count may result from attempts to work with slides which are too densely populated.)

The counting and sampling errors may therefore be handled as independent additive errors, related in the usual fashion, viz.:

$$Y_{c+s} = \sqrt{y_c^2 + y_s^2},$$

where Y_{c+s} = combined error of sampling and counting, y_c = counting error, and y_s = sampling error.

The combined error is given by equation (1) above. The counting error for a count length of 1,000 grains may be obtained from Table 4 (p. 498) of the previously published paper. For convenience, both equations are repeated below:

$$Y_{c+s} = 1.91\, x^{0.267}, \tag{1}$$

$$y_c = 1.39\, x^{0.269}. \tag{2}$$

It will make no difference large enough to influence a single analysis, or even the mean of several analyses, if the exponents are rounded to two figures, and it is not likely that the third is significant in any case. The sampling error alone will, therefore be:

$$Y_s = \sqrt{(1.91\, x^{0.27})^2 - (1.39\, x^{0.27})^2} \tag{3a}$$

$$= 1.31\, x^{0.27}. \tag{3}$$

Graphs of equations (1), (2) and (3) are given in Fig. 2. If a standard count length of 1,000 grains is used, total sampling-and-counting error may be read directly from the graph of equation (1). For count lengths other than 1,000 grains, the counting error as read from Fig. 1 is combined with the proper value read from the graph of equation (3), in the fashion described above. For instance, an analysis which yields a result of 7 per cent of desired constituent at a count length of 900 grains contains a counting error of 2.50 parts per thousand and a sampling error of 2.23 parts per thousand. The combined error of sampling and counting is therefore:

$$\sqrt{(2.50)^2 + (2.23)^2} = 3.36,$$

and the result should be reported as 7 ± 0.3 per cent.

If much work is to be done at some particular count length, it is a simple matter to construct a curve for total error at that count length, eliminating the computation and one of the graphical interpolations. The experimental analyses reported in this paper were run with a count length of 1,000 grains because this length is most commonly used in the College Park Laboratory.

As with the counting error, the sampling error will be symmetrically distributed about a composition of 50 per cent. That is, if the composition of a sample is given by

$$x_1 + x_2 = 100 \text{ per cent}$$

the sampling error (or counting error, or combined error) for either x_1 or x_2 is found by computation or graphical interpolation for the smaller of the two values.

ACCURACY.

That there is no systematic departure from a 1:1 correlation between weight and number frequencies for the beryl-feldspar standard mixtures may be inferred from Table 2:

In the table, the "experimental error of mean" is simply the difference between columns 1 and 2. The "expected error of mean" is the probable error of a single analysis as determined from equation (1) divided by the square root of the number of analyses run at each point.

TABLE 2.

% Beryl (weight)	% Beryl by Number (mean of all analyses)	Experimental Error of Mean	Expected Error of Mean
1.00	1.06	+0.06	±0.05
2.00	2.06	+0.06	±0.06
4.00	4.09	+0.09	±0.07
8.00	7.86	−0.14	±0.08
16.00	16.06	+0.06	±0.09
32.00	29.97	−2.03	±0.15
	32.52	+0.52	±0.12

Difficulty experienced with the 32-per cent point illustrates one of the limitations of the method. The low value (29.97) was the first obtained, and it was promptly assumed that the standard was faulty, since there seemed no reason for such a loss of accuracy unaccompanied by comparable precision loss between 16 per cent and 32. On the same day, the 8-per cent standard was run. These are the only determinations whose means fall below the respective weight percentages of the standards, and the only two in which the experimental error of the mean greatly exceeded the expected value. A measurement of the index of the oil used as a medium for these two suites of analyses showed an increase of several points over the labeled value. The 32-per cent standard was, therefore, rerun in a 1.553 oil, yielding a mean value of 32.52 per cent for 15 analyses.

The trouble was caused not by confusion of beryl for feldspar, but rather by loss of relief of beryl in the erroneously labeled index oil. (A comparable loss of relief of feldspar in the 1.553 oil seems to have introduced a small error in the second set also.) Relief-counting of this sort requires a certain minimum clarity of grains, since the identifications are made at high speed. The necessary minimum will vary with the observer and his equipment. (In this case, a different microscope was also used on the "doubtful" runs.) The loss of precision here involved would be imperceptible at very low percentages and would cause little trouble for values as high as 8 per cent. But errors of this sort are constant, and since further refinement of the method depends on evaluation of *non-instrumental* constant deviations, instrumental errors should be avoided at all costs.

For optimum results, quantitative analysis should be restricted to minerals that can be instantaneously and precisely differentiated from each other in a medium in which *all* constituents are readily observed. Where this condition is not attainable with untreated samples, the operator should resort to staining or etching. Where even this does not suffice, it is best not to "play with numbers." In problems of sufficient importance, the loss of accuracy

introduced by confusion or unclear definition of minerals should be evaluated by multiple analyses of specially prepared standards.

In general, the discrepancy between weight and number composition will be a function of the specific gravities and shapes of minerals in a given mixture. Excluding the extremes of flaky and acicular habit (which may cause trouble in sampling), these factors will express themselves largely or entirely as constant errors of counting, and by the use of weight-standards it should be possible to develop empirical correction factors, based on either specific gravity or shape, or on a combination of the two where it is not necessary or possible to isolate them. Preliminary experimental work indicates that corrections for shape are not required for mixtures of beryl, quartz, feldspar, calcite and fluorite in grains of 100- to 200-mesh size range.

CONCLUSION.

The over-all precision of micro-sampling and fragment counting by the methods described in this and the previous paper is shown to vary from 2 parts per thousand at 1 per cent of desired constituent to 5 parts per thousand at 50 per cent of desired constituent. Where neither specific gravity nor shape requires special correction, the relative accuracy of the method will range from 20 per cent at 1 per cent of desired constituent to 1 per cent at 50 per cent of desired constituent. Specific-gravity corrections can be applied as in Rosiwal analysis, and empirical correction factors for shape or combined shape and specific gravity effect may be developed as needed.

With the development of analytical expressions for counting and sampling error, the necessarily modest immediate objectives of this study have been attained. For the purpose of industrial petrography, the most useful expansion would probably be the development of shape-factor corrections for some of the common minerals. It would be desirable also to run parallel studies of counting and sampling error on both finer and coarser sands, though since the errors vary inversely it is possible that the total error of the two steps will not vary substantially with grain size, particularly in the coarser sizes. For the sampling of extremely fine sands (the "undersize" of the petrographer or "slime" of the mineral dresser) it may be possible to dispense with the microsampler, but the tremendous increase in number of grains per unit of weight may require refinement of counting technique or extension of count length.

A knowledge of the precision and accuracy of fragment counting and sampling opens the way to a systematic quantification of many standard petrographic procedures, and much could be accomplished in this respect on the basis of information already presented.

ACKNOWLEDGMENTS.

The work reported in this paper was done in the Petrographic Laboratory, Eastern Experiment Station, Federal Bureau of Mines, under the general direction of J. B. Zadra, Chief, College Park Division, Metallurgical

Branch. The project is under the immediate supervision of Alton Gabriel, at whose suggestion it was undertaken.

REFERENCES.

(1) Econ. Geol., vol. 39, no. 7, 1944, pp. 484–505. In this paper it was stated that counting error was not normally distributed, but no evidence was offered to this effect. Previous treatments of this and similar problems suggested a binomial error-distribution, but the experimental data show that in the present case this assumption leads to gross over-estimations of error even in moderately extended counts. Calculations of moments for a few of the count-groups suggest that a normal curve might be fitted to the experimental results. Accordingly, the reader should substitute "binomial" for "normal" distribution wherever the latter term occurs. Neither the reproducibility claimed for the data nor the utility of the results is affected by this revision.
(2) Manual of Sedimentary Petrography, Appleton-Century, 1938, pp. 357–359.
(3) Otto, G. H. Jour. Sed. Petrology, vol. 3, 1933, pp. 30–39.
(4) Anonymous notice. Eng. & Min. Journal, vol. 138, 1937, pp. 185–186.

College Park, M. ryland,
May 31, 1945.

NOTES ON THE DERIVATIVES OF THE TRIASSIC DIABASES OF PENNSYLVANIA.

W. HAROLD TOMLINSON.

ABSTRACT.

This article is a study of Triassic diabases in a belt extending from Goose Creek, Va., to Pennington, N. J. It gives an interpretation of the "diabase magma" as a mixed solution of "basaltic magma" and assimilated "acid magma." Rock types derived from the mixed magma are described. Solidification of the "diabase magma" is interpreted from a series of observed phases. Changes in chemical composition of the magma as solidification progresses and probable composition of residual solutions are noted.

Applications of this interpretation are made to theories of origin of the iron ores found along limestone contacts in part of the belt.

INTRODUCTION.

THE work on which this article is based was done in vacation time and on holidays during the past two years and was undertaken solely for my own satisfaction. The investigation has not been completed but the author feels that the results so far obtained may be of interest to some. The territory covered extends from Goose Creek, Va., to Pennington, N. J. Most of the quarries and exposures of the diabase within this belt were visited and the specimens collected, examined petrographically. This article is a generalization of the findings. The paragraph applying these findings to the iron ores is written from the standpoint of a study of the diabase. I have not made a study of the ore deposits.

THE MAGMAS.

The magma, from which the diabase has formed, consisted of a basic part and an acid part. These separate on solidification. The basic part of the magma solidifies before the acid part. I have come to regard these two parts of this diabase magna as of different origin. In this article I shall use the term "diabase magma" to mean the whole magma from which the granophyric type of the diabase has formed on solidification. The term "basaltic magma" will be used to indicate the basic part of the magma which I believe to be intrusive. The term "acid magma" will be used to indicate the acid part of the magma which I believe to have been assimilated and which may vary locally.

ORIGIN OF THE "BASALTIC" AND "ACID" MAGMAS.

It is generally believed that the basaltic magma has ascended from great depth, originating below the earth's granitic shell. I regard this as sound

speculation. As a corollary, I believe that a basaltic magma, arising from such a large reservoir and from such a great depth, should originally have been of uniform composition. Such variations as occur in the diabases formed from this magma in the upper reaches of its long ascent I would attribute to assimilation of various rock types along the journey upward. The "basaltic magma" in its rise must have contacted rocks of all compositions. Assimilation of basic types would not greatly change the composition of the "basaltic magma." The possibility of such assimilation will not be considered in this article. If however acid types such as granites were assimilated, the composition of the "basaltic magma" would be changed to that of the "diabase magma."

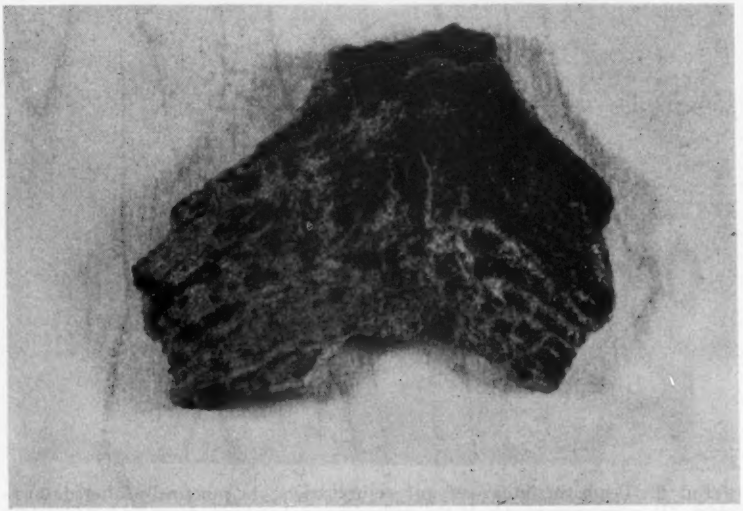


FIG. 1. Granophyric aplite penetrating and assimilating mica-schist. Specimen taken 30 ft. west of main diabase dike at Safe Harbor, Pa. Natural size.

It is known that basic magmas injected against granites will rejuvenate an aqueous magma from the acid rock but it is difficult to find proof that this "acid magma" is assimilated by the basic magma. The reason for this is the difference in specific gravity between the two magmas. The "acid magma" appears to rise through the heavier "basaltic magma," only a limited and small percentage being retained in the "diabase magma." If a high temperature were retained long enough by the "basaltic magma" probably all the "acid magma" would escape. The formation of granophyric diabase must therefore take place within a certain temperature range.

Bowen has described granophyres derived from rejuvenated granite magmas at Gowganda Lakes (N. L. Bowen: Jour. Geol., 1910). As far as I know,

no similar occurrence has been described in connection with the triassic diabases of Pennsylvania. There is, however, at Safe Harbor, Pa., a granophyric type of rock resting against the diabase which, I believe, has been formed from aqueous magma rejuvenated from granite by the basaltic intrusion. It is a pale, pinkish tan colored rock of fine grained aplitic texture. The composition and texture are not unlike that of a diabase aplite. Chemical composition of as pure material as available is shown in Table 3, col. 7.

At the north end of the large quarry at Safe Harbor the diabase cuts across a brecciated zone in the sediments. The granophyre has penetrated through this zone to a distance of fifty feet on the west side of the dike and ten feet or more on the east side. As the magma from which the granophyre formed was very fluid, the periphery of the formation feathers out in stringers through the sediments, Fig. 1.

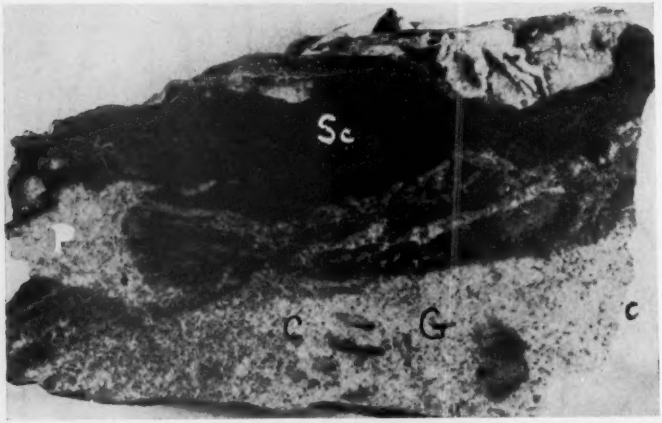


FIG. 2. Pegmatite in process of rejuvenation. Sc. thermally altered mica-schist. P. pegmatite in which the orthoclase is breaking down and stringering through the schist. G. large mass of granophyric aplite containing relict schist. C. angular small grey crystals are cordierite. Safe Harbor, Pa. Natural size.

At this locality the sediments were strongly impregnated in early time, with coarse grained pegmatite and associated quartz veins. Granite, from which the pegmatite derived, is supposed to underlie the sediments (Geol. Soc. Amer., S. P. 35, Dr. Ernst Closs) (U. S. G. S. Bul. 799, Drs. E. B. Knopf and A. I. Jonas). The granite-diabase contact is nowhere exposed. It is, however, possible to note the effect of the basaltic intrusion on the pegmatite, which is exposed in the quarry, although most of the material available for study must be taken from the rubble pile below the exposure. Specimens of pegmatite in schist within the diabase aureole show a breaking down of the pegmatite starting with the orthoclase and formation of a fluid magma which flows into the schist, Fig. 2. Chemical changes take place as the new magma

forms. Soda replaces potash in the feldspar. The potash becomes fixed in biotite. Micro-pegmatite forms around the quartz of the pegmatite. Much quartz remains after the new magma has flowed away. The new rock formed is a sodic granophyre similar to the larger masses of granophyre, which I believe, were derived from the underlying granite.

Specimens were found containing rounded, partially dissolved, fragments of granophyre in diabase. These fragments were rising through the "basaltic magma" and left a well marked trail in the form of a pipe. A section across

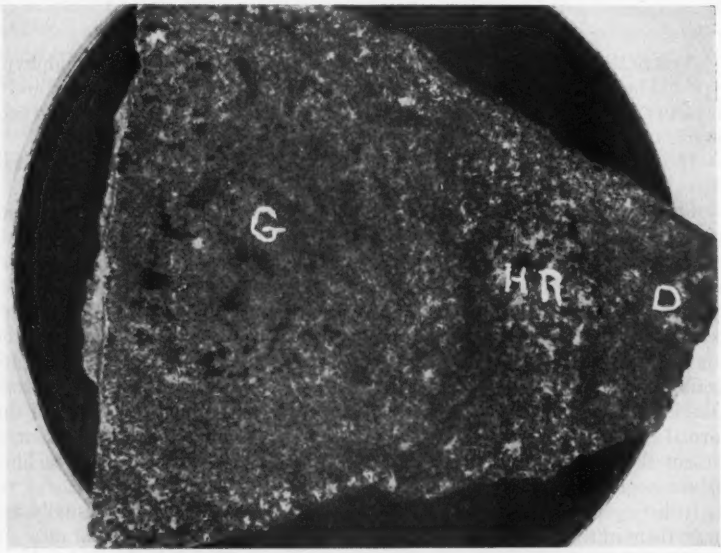


FIG. 3. Assimilation of granophyric aplite by diabase magma. G. rounded inclusion of granophyric aplite. HR. hybrid rock in reaction zone. D. highly granophyric diabase with hydration effects. Specimen from Safe Harbor, Pa. About 2 × natural size.

the granophyre-diabase contact shows granophyre, then a zone of hybrid rock in which cordierite is abundantly developed, then diabase. Sections across the pipe below the inclusion show a highly granophyric diabase in which the basic minerals have been altered by hydration, Fig. 3.

TYPES OF DERIVATIVES FROM THE "DIABASE MAGMA."

Earl V. Shannon has described the rock types that are derived from this magma as they occur at Goose Creek, Va. His article is contained in Proc. U. S. Nat. Museum, vol. 66, art. 2, 1924. The phases he describes cover the normal diabase, diabase pegmatite, albitic pegmatite, diabase aplite, diopside-hornblende veins and narrow seams of diabantite along slickensided fault

planes. His descriptions are very thorough and I could add nothing to them. The various phases he describes were found in all the larger bodies of the diabase that I visited, but the pegmatite phases are much more abundant at some localities than at others and are especially well developed at Goose Creek. Wherever found these pegmatitic phases are in largest development in, if not entirely confined to, the upper zones of the larger diabase bodies. This suggests an upward movement of the granophyric material through the heavier "basaltic magma" prior to or during solidification.

SOLIDIFICATION OF THE "DIABASE MAGMA."

Practically all of the diabase in the area I have studied is of granophyric type. The few occurrences of basic phases appear as local variations and I have not as yet studied them. All my tabulations are based on the granophyric type.

If quickly cooled the "diabase magma" freezes to a clear brown glass. Glass from a thin dike at Safe Harbor has index 1.588.

On slower cooling the "diabase magma" appears to split into two separate magmas which solidify more or less independently of each other; a "basaltic magma" which solidifies at relatively high temperature, and an "acid magma" which solidifies at much lower temperature. In small or medium size dikes and in normal diabase of the larger bodies, the "basaltic magma" crystalizes as a network of labradorite and augite and the "acid magma" remains in the interstices crystallizing later as granophyre. Examination of some twenty sections selected for normal appearance indicates that this interstitial crystallization of granophyric material represents about 6 per cent (average) of the normal diabase as measured by area in section. If more than 10 per cent is present the grain size of the basaltic minerals becomes coarser approaching diabase pegmatite.

In listing the primary minerals of this diabase, petrographers usually arrange them in three groups according to the stage at which they separate:

(1) Olivine, bytownite and a few phenocrysts. These are found in glassy dikes and in border phases which have been quickly chilled. They are rarely found in phases more slowly cooled.

(2) Labradorite and augite which crystallize more or less simultaneously at an early stage and represent the major constituents (about 90 per cent) of the rock. Titaniferous iron ore begins to crystallize out as an accessory at this stage and is included in this group.

(3) Alkali feldspars, quartz, micro-pegmatite, calcite, titanite, apatite, sulphides, all of which crystallize at a late stage. I would add magnetite to this group.

Groups (1) and (2) represent minerals derived from the "basaltic magma." Group (3) minerals mostly derived from the "acid magma." This article is concerned primarily with the "acid magma" minerals, group (3).

In the upper zones of the larger bodies of the diabase formation the "acid magma" is often concentrated as cores within blocks of crystallizing magma. When concentrated in this way the "acid magma" appears to act as a solvent

from which solute minerals of the "basaltic magma" crystallize. Normal diabase is of medium coarse and remarkably uniform grain. With increase in the percentage of "acid magma" the grain becomes much coarser. The change in grain size is gradual, increasing from the block walls inward. The percentage of granophyre in the rock increases with the grain size. This coarse grained rock with increased granophyre is the phase described as diabase pegmatite. The phase was found in all the larger bodies of the diabase visited and the type was found to be quite uniform at all localities.

In some pockets there appears to have been only enough concentration of the "acid magma" to form diabase pegmatite, but in many pockets further concentration has taken place. This final concentration is always rich in volatile elements and results in a core or vein of albitic pegmatite. There is no change in grain size or texture between the diabase pegmatite and the albitic pegmatite but the change in mineral composition is abrupt. At this stage of solidification magnesia and ferrous iron are depleted and lime much reduced. Alkalis, silica and volatile elements are all greatly increased. As water and carbonic acid become concentrated, albite and calcite crystallize out in place of labradorite. Hornblende takes the place of augite, but in greatly decreased amount. The volatile elements are now so abundant that they may attack the primary minerals in deuteric action. It is often difficult to distinguish between primary and secondary minerals. The fluid magma from these albitic pegmatite cores works upward to the surface in a dike. It is through these dikes that residual liquors escape into adjacent formations. Albitic pegmatites were found in all the larger bodies of the diabase visited, but the type was found to be quite variable. Volatile elements other than water and carbonic acid were often in evidence.

The three phases, normal diabase, diabase pegmatite and albitic pegmatite, are found blending into each other as a continuous series. Shannon regarded them as a continuous series derived by crystallization from the diabase magma, the albatic pegmatite bridging the transition period between primary crystallization and deuteric action. I would regard them as a continuous series formed from a mixture of two magmas which tend to separate on solidification.

The diabase aplites occupy fissures that cut across all three of the phases described above. As these fissures must have formed after solidification these aplites must be younger than the other phases. They are usually narrow straight walled veins differing structurally from the albitic pegmatites which work their way upward in dike fashion. The diabase aplites are composed entirely of minerals of the "acid magma," group (3). Their composition is similar to the interstitial crystallization of normal diabase. Compare cols. 4 and 5 in Table 1 and cols. 6 and 7 in Table 3. The magma from which the aplites form must have been rich in water. The vein walls usually show hydration effects. I have found small terminated stringers of aplite which I interpreted as contraction cracks filled by drainage from the walls. Many of the veins arise in depth and continue to the surface. I do not know how these veins are filled.

RESIDUAL SOLUTIONS OF THE "DIABASE MAGMA."

By following the changes in chemical and mineral composition through different phases as solidification progresses, it is possible to get an idea as to which elements are fixed in minerals in each progressive phase and which elements are likely to remain in residual solutions and be discharged into adjacent formations. The average mineral composition of the main phases is shown in Table 1. The elements present in the diabase as found by the

TABLE 1.

DISTRIBUTION OF MINERALS IN THE MAIN PHASES OF THE DIABASE.
Expressed in percentages from measurement of area in sections.

	Normal Diabase	Diabase Pegmatite	Albitic Pegmatite	Diabase Aplite	Micro-Pegmatite
(a) Augite	42	26			
Labradorite	46	37.5			
Micro-pegmatite	.6	22.5			
Diopside			5	3	
Hornblende			8		
Albite			50	57.5	56
Ilmenite	4	6.7	5	2.3	
Apatite	tr.	.7	2	tr.	1.5
Titanite	tr.	.3	1	1.8	1
Chlorite	.5			2.5	
Quartz			20	24.5	38

(a) includes a little orthorhombic pyroxene. Normal diabase, granophyric type. Average 22 samples. Type uniform. Diabase pegmatite. Average 20 samples. Type uniform. Albitic pegmatite. Average 3 samples. Type quite varied. Contains minerals not in list. Diabase aplite. Average 26 samples. Mostly of uniform type. Micro-pegmatite. Measurement of interstitial crystallization of normal diabase and diabase pegmatite in 22 samples. Measurements difficult to make and results probably not very accurate. Quartz and alkali feldspar of the micro-pegmatite are measured separated in last three columns.

spectroscope are shown in Table 2. The chemical composition of the main phases, taken from Shannon's article, are shown and compared in Table 3. His analysis of diabase pegmatite does not check with my measurements of mineral composition but is close enough for the purpose. It is probable that his sample was taken closer to the normal diabase wall than mine, hence is

TABLE 2.

SPECTROGRAPH OF NORMAL DIABASE FROM CORNWALL, PA.
Made by John Herman Laboratories, Los Angeles, Calif.

	10% plus	
	Silicon	
	1% to 10%	
Potassium	Magnesium	Aluminium
Sodium	Iron	Calcium
	.1% to 1.%	
Manganese		Titanium
	.01% to .1%	
Molybdenum	Vanadium	Copper
Nickel	Chromium	
	.001% to .01%	
Gallium	Cobalt	Silver
Boron	Zinc	

lower in "acid magma" minerals. From his analyses we can trace the fixation of the elements as solidification progresses.

Silica. Although part of the silica is fixed in silicates in each successive stage, the radical steadily increases in the residual magma reaching a maximum in the aplite. This is good evidence that silica will be carried out of the diabase by residual solutions.

TABLE 3.

ANALYSES OF MAIN PHASES OF DIABASE. ANALYSIS OF GRANOPHYRE.

	1 Normal Diabase	2 Diabase Pegmatite	3 % Increase	4 Albitic Pegmatite	5 % Increase	6 Diabase Aplite	7 Granophyre
Silica	51.56	52.94	2.67	68.74	29.8	71.60	67.30
Alumina	13.81	14.80	7.16	13.24	−10.5	13.16	15.70
Ferrous	11.32	12.00	6.00	1.38	−88.5	.38	.52
Ferric	.96	.16	−83.3	1.22	662.0	1.28	3.86
Magnesia	7.40	5.42	−26.8	2.02	−62.7	2.12	.70
Lime	10.08	8.32	−17.4	5.90	−29.00	3.76	.90
Soda	2.08	1.98	−4.64	5.76	191.0	5.92	6.40
Titania	1.48	2.32	56.7	1.44	−37.9	.34	.80
Phos.	.16	.28	75.0	.59	110.0	tr.	——

Columns 1, 2, 4 and 6 analyses of phases from Goose Creek, Va., by Earl V. Shannon as published in his article. Columns 3 and 5 show percentage changes in residual magma between successive phases. Column 7. Granophyre from Safe Harbor, Pa. Sample taken from north end of quarry about 10 ft. east of main diabase dike. Analysis by John Herman Laboratories, Los Angeles, Calif.

Alumina. The percentage of alumina remains remarkably constant during all stages of solidification. It is probable that some alumina is carried out by residual solutions.

Ferrous iron reaches a maximum in the diabase pegmatite corresponding to a maximum in the development of ilmenite. The radical is fixed in the augite and iron ore. Very little is left in the albitic pegmatite stage and it is practically eliminated from the aplite. It is very improbable that any ferrous iron is carried out by residual solutions.

Ferric iron increases after the diabase pegmatite stage but the percentage, except in certain veins which will be described later, is always very small. A small amount of ferric iron is probably carried out by residual solutions.

Magnesia is fixed in the augite (and olivine if present). The percentage is steadily reduced as solidification progresses and the radical is practically eliminated before the aplite stage. Most analyses of the aplite show under 1 per cent magnesia. It is very improbable that any magnesia escapes in residual solutions.

Lime is fixed in augite and labradorite. The percentage is steadily reduced as solidification progresses but the radical is not eliminated. Lime is probably contained in residual solutions.

Soda steadily increases in residual magma from each successive stage of solidification. It is probable that soda is carried out by residual solutions in large amount.

Titania reaches a maximum in the diabase pegmatite stage, corresponding to the maximum development of ilmenite. The radical is present, however, in all phases of the diabase and a little is probably carried out in residual solutions. Spectrographic examination of contact altered limestone made by the John Herman Laboratories showed titanium lines.

Phosphates. Phosphorus and fluorine are fixed in the mineral apatite which crystallizes from the "acid magma." As the mineral is one of the first to crystallize from its magma it seems unlikely that phosphorus and fluorine are carried out of the diabase except in cases where they are in large excess.

Sulphides are found in all phases of the diabase but increase in percentage as solidification progresses. Sulphides are undoubtedly carried out by residual solutions.

Of the elements likely to be carried out of the diabase into adjacent formations by residual solutions, soda, lime, part of the alumina, the sulphides and the trace of titania are derived from the "basaltic magma." The silica, part of the alumina, the ferric iron, water and most of the other volatiles are derived from the "acid magma."

APPLICATION.

Interpretation of this "diabase magma" as a "basaltic magma" with assimilated "acid magma," if correct, has application to the origin of the iron ores which occur as replacements of limestone along the diabase contacts in a limited area of the belt. The structural conditions of the deposits are such as to implicate the diabase with the origin of the ore.

It will hardly be doubted that these ores were laid down under reducing conditions. Ferric iron of the sediments is consistently reduced along all the diabase contacts. The ore deposits are principally magnetite but contain an appreciable amount of hematite. Magnetite pseudomorphs after hematite are frequently found. These conditions would require that the solutions depositing the ores must have originally been high in ferric iron.

The iron of the "basaltic magma" is practically all in ferrous form and this becomes fixed at an early stage of solidification. There is no evidence that any ferrous iron escapes. The ores could not be derived from residual solutions given off by this magma. It is only the diabases high in "acid magma" minerals that contain an appreciable amount of ferric iron. J. Volney Lewis in discussing his analyses of the diabases of New Jersey states that in general the alkalis, alumina and ferric iron vary as the silica and inversely as the magnesia, lime and ferrous iron (Geol. Survey of N. J., 1907, Part 4. J. Volney Lewis).

Ferric iron for the ores could be derived from the "acid magma," but except in certain localities the amount of ferric iron in this magma is insignificant. In the iron belt, especially at Cornwall, I have noted veins which I would designate as "ferric veins" in which the content of ferric iron is quite high. These veins are of albitic pegmatite type but differ from albitic pegmatite in mineral composition. They are composed of alkali feldspars, hornblende (partly relict), diopside and abundant small octahedra of magnetite.

Sulphides are present and other minor constituents derived from the "basaltic magma." A cross section of one of these veins is shown in Fig. 4.

The mineral composition of these "ferric veins" bears the same relation to the mineral composition of albitic pegmatite that the mineral composition of magnetiferous gneiss bears to the mineral composition of granite. I interpret the albitic pegmatite as assimilated granite which has separated on solidification and the "ferric veins" as assimilated magnetiferous gneiss which has separated on solidification in a similar way.

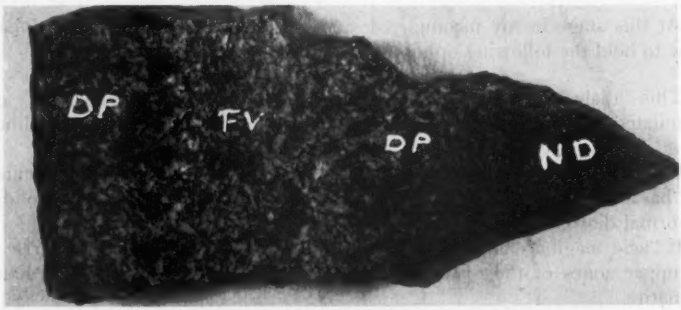


FIG. 4. Ferric vein from Cornwall, Pa. ND. normal diabase. DP. diabase pegmatite with ilmenite. FV. ferric vein with magnetite. Natural size.

These "ferric veins" contain the only pure magnetite that I have found within the diabase formation. Tests on the iron mineral of the diabase have, for me, always shown the presence of titania. Analyses were made of magnetic separates (the mineral is feebly magnetic) of various phases of the diabase with results shown in Table 4. Analyses of the ore show no titania or only traces. Analyses of the iron mineral of the "ferric veins," cols. 5 and 6, show some titania, but this, I am convinced, is contamination from the vein

TABLE 4.

ANALYSES OF MAGNETIC CONCENTRATES.

	1 Normal Diabase	2 Normal Diabase	3 Diabase Pegmatite	4 Albitic Pegmatite	5 Ferric Vein	6 Ferric Vein
FeO	71.4	35.30	60.20	50.56	46.70	37.90
Fe_2O_3	13.1	56.18	29.60	16.98	46.76	56.25
TiO_2	15.5	8.52	10.20	32.39	6.64	5.80

Analyses calculated to 100 per cent to allow for impurities in concentrates. Column 1, normal diabase from French Creek Quarry, Pa. A basic type. Column 2, normal diabase from Cornwall, Pa. Average two samples taken from dump. Column 3, diabase pegmatite from Goose Creek, Va. Column 4, albitic pegmatite from Elizabeth Mine, French Creek, Pa. Sample taken 25 ft. below ore. Column 5, ferric vein, Cornwall, Pa. Sample taken from dump. Column 6, ferric vein, Robeson Quarry, Pa. Analyses by John Herman Laboratories, Los Angeles, Calif.

walls which contain ilmenite. Carefully selected crystals of magnetite from the center of the veins did not show titania in tests.

I offer one further argument to connect these ores with the magnetiferous gneisses. The cerium epidote, allanite, is frequently found in the ore deposits. No cerium minerals have been reported from either the diabase or the unaltered limestone, but allanite is an abundant associate of magnetite in the magnetiferous gneisses.

SUMMARY.

At this stage in my incompleted study of this diabase formation, I have come to hold the following opinions.

This "diabase magma" was a mixed solution of "basaltic magma" and assimilated "acid magma." The two magmas separate in process of solidification.

Under the near surface conditions to which our observations are limited, the "basaltic magma" will retain up to 6 per cent of "acid magma" and solidify as normal diabase of granophyric type.

If "acid magma" has been assimilated in higher percentage it will rise to the upper zones of the magma body forming diabase pegmatite and albitic pegmatite.

Large bodies of this "basaltic magma" will rejuvenate an aqueous magma from contacted granite or pegmatite.

Fragments of granite caught in the "basaltic magma" will rise through the magma being assimilated in their ascent (Safe Harbor).

The iron ores could not be derived from the "basaltic magma."

The iron ores could be derived from the "acid magma" provided the assimilated acid rock was originally high in ferric iron.

ACKNOWLEDGMENTS.

I wish to express my thanks to the operators of all mines and quarries in the belt for their kind permission to visit and collect from their properties and to all superintendents for their courteous assistance. My neighbor, Albert E. Gibson, made the photographs. To my friend and companion on many trips, Wm. Leigh Smith, I owe a debt of gratitude for much assistance in collecting and for hauling home many hundreds of pounds of specimens with utter disregard to the tensile strength of springs.

SPRINGFIELD, PA.,
September 1, 1945.

THE FINENESS OF GOLD, WITH SPECIAL REFERENCE TO THE MOROBE GOLDFIELD, NEW GUINEA.

N. H. FISHER.

CONTENTS.

Part II.

PAGE

Comparisons with other localities
General 537
Epithermal deposits
Localities with high quality gold 543
Hauraki, New Zealand 545
Sumatra 545
Philippines and Japan 546
Western North America 546
Central and South America 547
Transylvania 547
Intermediate group 548
Mesothermal deposits
Morobe goldfield 549
New Zealand 549
Queensland 550
Southeastern Australia 552
North America 553
Chile 554
Hypothermal deposits
Australia 554
Asia 555
North America 555
South America 555
Fineness of gold in the Homestake Mine—Table 5 556
Pyrometasomatic deposits 556
General considerations 556
Resumé 560
Practical applications 562
Acknowledgments 563

COMPARISONS WITH OTHER LOCALITIES.

General.

The paucity of readily available records has been a severe handicap in making comparisons with other auriferous areas. The fineness of the gold in any area or mine is often not recorded unless it possesses some outstanding abnormalities, and few attempts have been made to account for variations in fineness. Even where recorded it is not always stated from what type of ore

it has been obtained or whether it may be taken as representative. Even in the excellent series of Bulletins and Professional Papers published by the United States Geological Survey, dealing with the different gold-bearing districts of the United States, it is rare to find more than a passing reference to the fineness of the gold. Many reasons contribute to this. One of the most prolific sources of information on the fineness of the gold in any area is the alluvial returns, for the alluvial miner is always acutely conscious of the fineness of his bullion. His clean-up represents to him the number of ounces that his scales show, but he knows that the price he receives for it depends upon its fineness. However, in most areas the alluvial gold, if any appreciable amount was ever present, has long been worked out, and the records are not readily accessible. The next source of information with regard to gold fineness is battery returns (giving due allowance to the possible presence of native silver), and many modern mining plants dispense with amalgamation processes altogether, especially if the gold is finely divided. No other form of recovery gives a reliable guide to the grade of the gold as it occurs naturally, unless the ore is entirely devoid of silver minerals, which rarely happens. Otherwise to ascertain the fineness of gold in a mine is a laborious process, involving the separation by mechanical means, possibly with the aid of mercury, of sufficient gold to run a bullion assay, and this is not often done except by large companies or by research workers. Even when it is, and all care is taken to ensure that the fineness of the gold is not altered in the extraction process the sample may not be representative of the whole lode, unless confirmed by similar samples from other parts of the mine.

Another source of uncertainty is the changes that might have taken place through solution, redeposition and leaching, in the gold between the time of its original deposition, and the time of collection for assay, whether from alluvial, or from the outcrop, or at various depths down the lode. The effects of such variations have already been shown for the Morobe goldfield, both with regard to alluvial and lode gold, as it is part of the aim of this investigation to find out how the fineness of the gold may be altered by its subsequent history as well as to ascertain the relations between the original fineness and the conditions of deposition.

Table 4 has been prepared, showing the fineness of gold and the range in fineness in those gold-bearing districts for which it has been possible to collect data. The silver/gold ratio, the age of mineralization and the type of igneous intrusive associated with the origin of the ore are also given where obtainable. The lodes of large gold-bearing districts showing one fineness only, particularly belonging to earlier periods, have for the sake of brevity been combined under one heading.

The deposits or districts are here divided according to Lindgren's [28] classification into epithermal, mesothermal and hypothermal types, but a few of the first division, whose mineral associations and general conditions of deposition suggest a rather deeper origin than most of the epithermal veins, are grouped together separately at the end of that division. These probably are referable

[28] Lindgren, W.: Mineral deposits.

TABLE 4.
GOLD FINENESS DATA.

TABLE 4.

GOLD FINENESS DATA.

Country	District or Mine	Gold Fineness	Silver/Gold Ratio	Age of Mineralization	Associated Intrusives
Epithermal Deposits					
New Guinea	Morobe	500–620	1–100/1	Late Pliocene	Qz.-biotite porph.
Fiji, Vanawai	Mount Kasi	950	very low	Miocene	Andesites, etc.
Tavua	Emperor	910–950	very low	Miocene	Andesites, etc.
New Zealand, Hauraki	Thames	625–750(670)	—	U. Mioc.-L. Mioc.	Andes. and dacite
	Waihi	645	6/1	Upper Miocene	Dacite
	Karangahake	645–850	20/1	Upper Miocene	Andesites, etc.
	Waihi Beach	500	—	Pliocene	Rhyolite?
Sumatra	Simau	600	12/1	Late Tertiary	?
	Redjang Lebong	500–600	7/1	Late Tertiary	Dac. and andes.
	Mangani	500–600	50–100/1	Late Tertiary	Andesite
Japan	Omiri	650	—	Late Tertiary	Liparite
California	Randsburg	730–780	—	Early U. Miocene	Rhy., andes.
	Bodie	675	2/1	Tertiary	Andesite
Idaho	Florence and Warren	550–700	—	Post-Oligocene	Granite
	Silver City	c.500	15–130/1(30/1)	Post-Miocene	Rhyolite?
	De Lamar	500	6– 30/1(20/1)	Post-Miocene	Rhyolite
Montana	Marysville	c.750	30/1	Late Tertiary	Dac. dikes intruding Boulder Batholith
	Jay Gould	506–536	—	Late Tertiary	Granitic stock
Colorado	Cripple Creek	900	1/10	Late Tertiary	Volcanic neck intruded by phonolite and syenite dikes
Nevada	Comstock	c.500	40/1	Late Tertiary	Andes., diorite, diabase
	National	c.500	1/1	Late or Post-Mioc.	Volcanics, latite, rhyolite
	Jarbridge East	580	2/1?	Miocene-Pliocene	Rhyolite

TABLE 4—*Continued.*

Country	District or Mine	Gold Fineness	Silver/Gold Ratio	Age of Mineralization	Associated Intrusives
Epithermal Deposits—Continued					
Nevada—*Continued*	Tonopah	500–650	105/1	U. Mioc. or L. Plioc.	Andesitic tuffs, etc. intruded by acidic rocks
	Goldfield	up to 990	1/3	U. Mioc. or L. Plioc.	Andesite sill in tuffs
	Manhattan	527–717	2/5	U. Mioc. or L. Plioc.	Andesite and rhyolite?
Central Amer.	Nicaragua	750(All.)	2/1	Tertiary	Andesite
	Honduras	550–570(All.)	High	Tertiary	Andesite
Argentina	Gualilan	650–750	—	Tertiary	Dacite
Transylvania	Verespatak	500–605	—	Miocene	Dac. rhy., andes.
	Boicza	600–700(668)	1/2?	Miocene	Quartz porphyry
	Ruda-Barza	600–700	—	Miocene	Andesite, dacite
	Karacs-Czebe	750–795	—	Miocene	Andesite
New Guinea, Morobe G. F.	Lower Edie, etc.	700–800(All.)	10/1	Miocene?	Qz.-biotite porp.
New Zealand	Coromandel	750–800	—	Eocene-Miocene	Andesite, dacite
Burma	Choukpazat	850	—	Tertiary	Andesite intruded by qz. dior.
Madagascar	Andavakoera	658–765	—	Lower Tert.?	Stocks of syenite, etc.
Colorado	Camp Bird	740	Probably not high.	Miocene	Andesite tuffs and breccia
Colombia	Titiribi	750–800	20/1	Tertiary	Andesite dikes and sills
Mesothermal Deposits					
New Guinea	Morobe	850–930(All.)	50–1/1	Mesozoic	Granodiorite
New Zealand	W. Coast, S. Is.	950(All.)	—	U. Jur.-L. Cret.	Gran. intrusives
Queensland	Charters Towers	760–860(825)	—	Post-L. Dev., pre-Tert.	Diorite-porp. dikes
	Gympie	820	—	Permo-Carb.	Granite; andes. dikes

TABLE 4—*Continued.*

	Gympie	820	—	Permo-Carb.	Granite; andes. dikes

TABLE 4—*Continued.*

Country	District or Mine	Gold Fineness	Silver/Gold Ratio	Age of Mineralization	Associated Intrusives
Mesothermal Deposits—Continued					
Victoria	Bendigo	940–980	very low	Devonian	Granodiorite
	Ballarat	980	very low	Devonian	Grano.; porp.; felsite
	Woods Point and Walhalla	773–802(Reef)	very low	Devonian?	Grano.; diorite-porph.; lamprophyre
Alaska	Fairbanks	780–906(815)	—	U. Jur. or L. Cret.	Quartz-monz.
	Rampart	915–941(923)	—	U. Jur. or L. Cret. and possibly later	Granodiorite
Brit. Columbia	Bridge River	800–825(All.)	—	Cretaceous	Augite-diorite
Nova Scotia	——	930–981(955, All.)	—	Devonian	Granite
Oregon	Virtue	850–950	—	Lower Cret.	Granite, etc.
	Phoenix	800–900	—	Lower Cret.	Granitic intrusives
California	Mother Lode	790–840	—	Upper Jur.	Grano. batholith
	Grass Valley and Nevada City	730–950(800–860)	1/4	Upper Jur. or Lower Cret.	Small grano. stocks
	Alleghany	796–869	—	Upper Jur.	Granitic intrusives
Montana	Philipsburg	815–866	high	Lower Tert.	Granodiorite
	Elkhorn	850–900	1000/1	Lower Eoc.	Quartz-porph. close to Boulder batholith
	Garnet Range	906(All.)	2/1	Lower Tert.	Granodiorite
	Dillon	830–865	—	Lower Tert.	Boulder batholith
Idaho	Coeur d'Alene	720–870(All.)	high	Cretaceous	Monzonites
	Boise	700–900	—	Mioc. and earlier	Porphyry, diorite, etc.
Colorado	Breckinridge	750–900	—	U. Cret. or L. Tert.	Porphyry (qz.-monz.)
	Giplin	730–870	—	Lower Tert.	Quartz-monzonite
New Mexico	Elizabethtown	790	—	Lower Tert.	Porphyry

TABLE 4—*Continued.*

Country	District or Mine	Gold Fineness	Silver/Gold Ratio	Age of Mineralization	Associated Intrusives
Mesothermal Deposits—Continued					
Chili	Atacama	850?	fairly high?	Lower Tert.?	Grano. with porp. dikes
	Guanaco	944	—	Tertiary	Dacites, etc.
Virginia	Piedmont	850–900	1/5	?	Granite?
Georgia	Battle Branch	700–910(850	—	Upper Carb.	?
W. Australia	Coolgardie	882–972	low	Pre-Cambrian	Granite; diorite-porph. dikes
	Kalgoorlie	910–999	low	Pre-Cambrian	Granite; porph.; oprph. dikes
	Meekatharra	c.900	low	Pre-Cambrian	Porphyry dikes
India	Kolar	889–920	—	Archaean	Acid intrusives?
				Archaean (later)	Diabasic dikes
Brit. Columbia	Rossland	c.870(All.)	3/2	Late Jur.	Monz.; grano.
S. Dakota	Homestake	820–849(835)	3/7	Pre-Camb. and possibly Tert.	Porp. dikes
Venezuela	El Callao	915(All.)	—	Pre-Camb. or later	Granite?; qz.-porph.
Brazil	Morro Velho	790–810	—	Pre-Cambrian	Dior. and gran. dikes
Montana	Cable Mine	very high	—	Lower Tertiary?	Quartz-monzonite
Utah	Bingham	850–900(All.)	400/1	Cretaceous	Monzonite-porphyry

to the lower portion of the epithermal zone, approaching, if not quite corresponding to, Graton's [29] leptothermal class.

The fineness of the gold in the table is as given in the various sources from which it has been obtained and these sources seldom mention the silver content of the bullion, so it has to be assumed that nearly all of the remainder is silver, as in the case of most alluvial and vein gold, free from impurities, in which the gold and silver generally add up to about 990. In some cases as in the figures for Fiji, where the bullion apparently contained large quantities of base metals, and both gold and silver fineness were supplied, the fineness has been recalculated to the $\frac{Au}{Au + Ag}$ basis. In most other localities the fineness is of bullion from lode mines, presumably from amalgamation. Where obtained only from alluvial gold shedding from the reefs it is indicated by (All.) after the fineness figure. Often it is not certain what processes were used to obtain the bullion, and some authors merely give the bullion fineness without regard to whether it corresponds to the true fineness of the gold or not. In a similar manner the silver/gold ratio given is very seldom the true silver/gold ratio of the ore as determined by assays in the mine, but is nearly always taken from the production figures and represents only the ratio of the amounts of silver and gold recovered by whatever processes may be in use. Generally in mines carrying high silver values associated with the gold, some form of cyanide treatment is used at one stage or another during the extraction. Even so it is by no means certain that all, or even the greater portion, of the silver will be recovered, particularly in the case of Tertiary manganiferous ores. At Edie Creek for instance, by combined amalgamation and cyanidation, silver recovery in the New Guinea Goldfields mill varies from 15 to 40 per cent of the silver content of the ore, and a similar percentage was obtained by direct cyanidation at Day Dawn South, and at Day Dawn by cyaniding the tailings from battery treatment. Consequently in most cases, particularly epithermal ores where a high silver/gold ratio is given, the true silver/gold ratio would be even higher than that shown, depending largely on the type of ore and whether the mill is designed primarily to recover the gold or the silver or both.

The age of mineralization is taken from the most reliable authority available, and the associated intrusives in most cases indicate the igneous rocks considered by those who have studied the deposits to be genetically connected with the lodes, or at least to have been derived from the same magma. In some cases it has been possible to indicate only a geographical association.

Epithermal Deposits.

Localities with High Quality Gold.—Table 4 shows that the gold of the epithermal deposits ranges mostly from about 500 to 750 fine, with a few isolated instances returning a much higher grade of gold, *e.g.*, Fiji 910 to 960; Cripple Creek over 900, and Goldfield, Nev., up to 990. These three localities have one essential feature in common, that the gold of high fineness is in each

[29] Graton, L. C.: The depth zones in ore deposition. ECON. GEOL., vol. 28, no. 6, 1933.

case at least partly the result of oxidation processes, *i.e.,* residual fine gold from which any associated elements have been leached out. Cripple Creek and the Fiji occurrences are particularly comparable as in both cases the gold was deposited as tellurides, the gold obtained was derived from the oxidation of those tellurides, and the silver content of the ore is very low. In Fiji the proportion of silver must be exceedingly small, as the bullion showing such a high degree of fineness is derived mainly from cyanidation. At Mt. Kasi the near-surface ore is in a highly oxidized condition and the gold in a fine state of division, but [30] no tellurides are present. Because the cyanide bullion is of such a high grade, over 950, it is obvious that little silver was available to combine with the gold, or some of its secondary minerals would be dissolved by the cyanide. The gold in the near-surface ore at the Emperor mine [31] results largely from the oxidation of tellurides, and in the first few years of operation the cyanide bullion, as at Mt. Kasi, was of high quality, 910–960. This figure has progressively decreased, probably due to a greater proportion of non-surface ore being mined, and was down to 800 in 1941, 774 in 1942, and 757 in 1943. Loloma gold mines have been treating one described by White [32] as sulpho-telluride by roasting and cyanidation combined with straking and amalgamation. Unfortunately the returns from the two processes are not separated and the combined bullion has a true fineness varying from 701 in 1937 to 833 in 1938, and 780 to 800 thereafter. The silver content of the telluride, which according to Silva [33] is almost entirely sylvanite ($AuAgTe_2$), would alone be sufficient to account for the silver in the bullion, so that any primary gold which may have been deposited would be of high grade. Costello's block, also at Tavua, produced gold from highly oxidized ore by straking and amalgamation only, 938 to 945 in fineness, in close conformity to that obtained from the Emperor mine from presumably similar ore by cyanidation.

Similar conditions exist at Cripple Creek, Colorado, where the depth of cover at the time of ore formation is estimated [34] at from 500 to 3,000 feet. The gold occurs as tellurides and the proportion of silver to gold is about one to ten. The oxidized gold from outcrops was of very high purity, and probably much of the small amount of silver in the sulphide ores is contained in the gold silver tellurides, sylvanite and kennerite, though calaverite (AuTe with little silver) is easily the dominant telluride. Small amounts of silver are also present in galena and tetrahedrite, for the silver content of the ore rises considerably when the proportion of these two minerals increases.

The ores of Goldfield, Nevada, are among the most interesting in many respects of the whole epithermal range and have received much attention from American geologists. Though deposited probably less than 1,000 feet below the surface at the time of formation,[35] the gold is of exceptionally high grade.

[30] Mt. Kasi Mine, Fiji: Chem. Eng. and Min. Review, Sept., 1935.

[31] Emperor Mine and Mill: Chem. Eng. and Min. Review, Nov., 1938.

[32] White, T. M.: Inspector of Mines, Fiji. Private communication, Loloma Mine and Treatment Plant. Chem. Eng. and Min. Review, March, 1938.

[33] Silva, H. F.: Assaying rich telluride gold ores. Chem. Eng. and Mining Review, Nov., 1939.

[34] Lindgren, W., and Ransome, F. L.: Geology and gold deposits of the Cripple Creek District, Colorado. Prof. Paper No. 54, U. S. G. S.

[35] Ransome, F. L.: Geology of the Goldfield District, Nevada. Econ. Geol., vol. 5, 1910.

Tellurides occur in the ore, petzite, sylvanite, and hessite, and the complex mineral, goldfieldite, but only in comparatively small amounts, though it is probable that high assays over 990 fine from this field are due to oxidized gold derived from the tellurides. However, the free gold is also undoubtedly of high fineness, which is explained by the fact that on the whole very little silver was available in the ore-bearing solutions at the time the gold was being deposited.

Hauraki, New Zealand.—The Hauraki goldfield in New Zealand is fairly typical of Tertiary andesitic gold deposition. Tellurides are not abundant and occur mainly in the Thames section. Mineralization took place over three different periods, extending into Pliocene time. The gold fineness is higher in the north than in the more southerly portions of the field (in fact there is a general decrease in gold fineness in the Hauraki field from north to south) and the silver content of the ore seems to be lower. In the Thames field, where bonanza ores are prevalent, the fineness varies considerably, averaging about 670. Higher values are possibly due to oxidation of tellurides, as at the Waitangi claim, where gold of fineness 813 was found associated with hessite. Fraser [36] states that in the Tapu and Tararu valleys the gold in veins in proximity to or not far above the pre-Tertiary basement rocks is of higher value, notably 740–750. He quotes the range at Tapu of gold in argillite as 722 to 806 and that in andesite, higher up, as 721 to 752.

The gold of the Waihi mines averages from 645 to 650 in fineness and goes up as high as 700, but no data are available as to its variation, if any, with depth. The mineral associations are very similar to those on the Morobe Goldfields, except that adularia has not yet been recognized in New Guinea. The ores at Karangahake are similar in age, mineral and geological associations and gold fineness to the Waihi lodes, except that in a small branch off the main Maria or Talisman vein, gold nearly 900 fine was found, associated with calcite, siderite, and stibnite. At Waihi Beach low grade gold only 500 fine and deposited under very near surface conditions is found in flows of Pliocene rhyolite, similar to that which overlies the goldbearing rocks at Waihi.

Sumatra.—Gold occurrence in the Netherlands East Indies, particularly in Sumatra, also shows many features of similarity with the Morobe goldfield, notably in the presence of late Tertiary ores with gold of low fineness, and gold of pre-Tertiary origin and fineness 800 to 900, obtained from alluvials. The writer has visited the goldfields of South Sumatra, and was able to gain first hand information as to the method of occurrence of the gold, not only in the mines examined personally, but also in other areas in the Netherlands Indies.

The Mangani mine exhibits the most similarity to the Morobe Late Tertiary lodes, the mineralogy being practically identical, including the presence of refractory manganese silver minerals; the grade of the ore decreases with depth, generally becoming unpayable at or not far below the bottom of the oxidized zone; the gold fineness is similar; the silver content is very high, and first rises, then decreases with depth from the surface; and secondary enrich-

[36] Fraser, Colin: Geology of the Thames Subdivision, Hauraki, Auckland. Bull. No. 10, N. Z. G. S.

ment is important. The Redjang Lebong orebody shows one remarkable feature of similarity with the Edie lodes, and that is the occurrence of concentric nodules of chalcedonic quartz carrying gold, but these are not developed at Edie Creek either to the perfection or to the extent that they occur at Redjang Lebong. The lodes of the Simau gold mines at Tandaiberg occupy a very strong, steeply inclined fault system in gently dipping Tertiary shale, tuff and agglomerate. The lode material consists of quartz and breccia, and the principal metallic minerals are galena, sphalerite, pyrite and chalcopyrite. Secondary enrichment is not important but primary enrichment has occurred near faults. The bottom of oxidation, approximately No. 5 level, 500 feet below the highest part of the outcrop, does not correspond to any noticeable change in gold content. The gold is mainly finely divided, but a sample from the 300 foot level sufficiently large to be assayed ran 600/368 fine. Dr. C. Schouten [37] has made a study of polished sections of the Simau ores and he states that the gold occurs as electrum Au_2Ag_3 (549.3) or Au_3Ag_4 (578.2), and further that comparison of the electrum from different levels in the mine with prepared alloys of known composition indicates a decrease in fineness with depth, that of the upper levels approximating AuAg (646.3) and the low levels $AuAg_2$ (477.5) in composition. He also states that a little free gold of supergene origin is present as well.

Philippines and Japan.—Conditions of gold deposition in the Philippine Islands are similar to those in Sumatra and New Guinea. Most of the lodes are associated with andesites or diorites, largely of late Tertiary age, but alluvial gold of high quality from earlier sources is also found. Philippine gold obtained from placer and lode mines has an average fineness of from 700 to 850,[38] though extremes in either direction are found.

Similarly in Japan [39] the gold fineness varies in veins from 566 to 926 and in placers from 620 to 904. Most of the gold mineralization took place in several stages in the Tertiary, principally in the late Tertiary, associated with volcanic extrusives. The mineral assemblages in the veins are characteristic epithermal, similar to Edie Creek, fineness of the gold is low, silver/gold ratio high, from 7 to 100/1, and manganiferous material is often present in the oxidized ore. An earlier epoch of gold mineralization was connected with granites intruded in late Mesozoic and early Tertiary times and this was probably responsible for the higher grade gold.

Western North America.—The examples listed of the great late Tertiary epithermal province of Western America call for little comment. As far as possible the principal districts which are producing or have produced gold are represented, except a few for which detailed figures on the gold fineness could not be obtained, such as Republic, Washington; Tuscarora, Nevada; and the Mexican veins, but there is no reason to suppose that the conditions prevailing in these areas are not similar to those given. It should be mentioned that the fineness quoted for the Randsburg district does not include the yellow Aster

[37] Schouten, C.: Verhandelingen v. h. Geol.—Mijnbouwkundig Genootschap v. Nederl. en Kolonien, Mijnb. Serie, Deel 11, pp. 161–233, 1928.

[38] Director of Mines, Manila. Private communication.

[39] Emmons, W. H.: Gold Deposits of the World, pp. 361–371.

mine, the principal producer, in which the lode is of much deeper-seated origin and which carries high-grade gold and very little silver. It is noticeable that the districts with fineness down to 500 or so are generally late or post-Miocene, the Miocene lodes being somewhat higher in grade. Detailed data on the depth from the surface of deposition of the ores are seldom procurable, owing to the difficulty of reconstructing the probable topography at that time. The fineness given in most cases probably represents fairly accurately the gold as deposited, though in some districts it is possible that secondary enrichment may have purified the gold of the upper levels. The silver/gold ratio is in most cases the ratio of the bullion produced, consequently, as previously explained, lower than the average assay relationships in the mines.

Most of the ore deposits of Mexico are primarily silver lodes containing gold in varying amounts. The most important gold veins are those of El Oro. Alluvial gold in Mexico ranges from 500 to 999,[40] though of course the latter figure is exceptional. The lower limit of 500 is interesting, in that it shows that even in a region of the most abundant silver, the proportion of gold in the naturally formed gold-silver alloy does not fall below about 50 per cent.

Central and South America.—Most of the gold in Central America is obtained from lodes in Tertiary effusive rocks, occurring under conditions generally similar to other epithermal provinces, and usually carrying low grade gold. An important exception with regard to gold fineness is the famous Espiritu Santo mine in Panama. This orebody is a pipe-like mass of decomposed andesitic breccia, and the rock fragments are surrounded by concentric shells of pyrite, sphalerite and galena, and calcite, with acicular quartz crystals. Gold occurs usually crystalline or in wires or strings, and, according to Maclaren,[41] is 932 to 940 fine. Little silver seems to be present in the ore and this may explain the high fineness of the gold, or the high value quoted may be from surface oxidized ore.

Lindgren[42] states that the great majority of the deposits of the Pacific Coast of South America, though of Tertiary age, are of the mesothermal or hypothermal type exposed by heavy erosion. Most of the gold exceeds 850 fineness. A few lodes formed near the surface are found in Colombia, Peru, Chili, and Argentina. Alluvial gold 610 to 650 has been derived from deposits associated with late Tertiary volcanics, but the average fineness of placer gold in Colombia is 834/1366. Maclaren[43] states that the average fineness of vein gold is only 698, but later figures are higher. Some of the Argentine gold veins occur in later-Tertiary eruptives, and the gold of these is of low fineness, as at Gualilan, 650 to 750.

Transylvania.—The important gold-bearing region of the Transylvanian Erzegebirge is a typical upper Tertiary epithermal province with characteristic mineral associations. Tellurides, first discovered here, are found in parts of the field, and manganese minerals are also present in places; gold fineness is around 600, with higher grades usually associated with the oxidation of tellurides.

[40] Director, Institute of Geology, National University, Mexico. Private communication.
[41] Maclaren, J. M.: Gold. The Mining Journal, 1908, p. 613.
[42] Lindgren, W.: Mineral Deposits, p. 886.
[43] Maclaren, J. M.: Op. cit., p. 626.

Intermediate Group.—A few deposits have been segregated out of the epithermal group because they all similarly show characteristics suggesting that they belong to the deeper portion of that zone. The auriferous material carrying gold of fineness 700–800, associated with the contact zone of the lower Edie type quartz-biotite porphyry of the Morobe goldfield, which was certainly not intruded close to the surface, carries in the few cases found in situ galena, pyrite, sphalerite and bornite in a gangue mainly of quartz. Occasional high silver assays are probably due to the presence of argentiferous galena, and samples both from the Lower Edie and the Waria area gave an average silver/gold ratio in the vicinity of 10/1.

The gold lodes of Coromandel, New Zealand, occur low down in the volcanics, sometimes extending into the underlying pre-Tertiary rocks, and the mineral suite, quartz, calcite, native arsenic, stibnite, pyrite, arsenopyrite, chalcopyrite and gold 750 to 800 fine, sufficiently suggest affiliations with the mesothermal group to place the deposits low in the epithermal.

The Choukpazat veins in Burma lie in Tertiary andesitic tuffs, and their origin is probably connected with the andesite or with intrusive quartz-diorite dykes. The gangue is quartz, with calcite in the lower levels, and the mineral assemblage constitutes pyrite, galena, chalcopyrite, franklinite and altaite, the last two associated with the gold, which is usually in a fine state of division. The plate bullion averaged 850 fine.

Most of the gold mining areas in Madagascar are in pre-Cambrian rocks and carry high-grade gold. The most important, however, at Andavakoera in the north of the island, are near the contact of Triassic sediments with the schist and gneiss, all of which are invaded by stocks of syenite, and other intrusives. Emmons [44] says that the deposits are post-Triassic, probably Tertiary, and suggest epithermal conditions. The gold is 658 to 765 fine.

The Camp Bird mine is quoted by Graton [45] as transitional in the lower levels from epithermal to his leptothermal zone. The upper part of the vein contains a characteristically epithermal assemblage of minerals, but at greater depths the percentage of base metals increases and specularite makes its appearance.

The ores of the important Titiribi district in Colombia, producing gold 750 to 800 fine, are said by Emmons [46] to have been probably deposited near the surface, in genetic connection with andesitic magma. They occur in rocks of the basement complex, in Tertiary sediments or in andesitic sills, in nearly all cases near the andesite contacts. Minerals are quartz, calcite, dolomite, pyrite, arsenopyrite, sphalerite, galena, bournonite, chalcopyrite, jamesonite, tetrahedrite and stibnite. This assemblage is by no means altogether typical of ores formed close to the surface, while practically all of them are mentioned by Lindgren in his list of minerals found under mesothermal conditions, so that it seems reasonable to place the Titiribi lodes at least low down in the epithermal range. The gold deposits of Zaruma, Ecuador, with free gold 734 [47] fine and a silver/gold ratio of about 3/1, probably belong to a similar horizon.

[44] Emmons, W. H.: Gold Deposits of the World, p. 448.

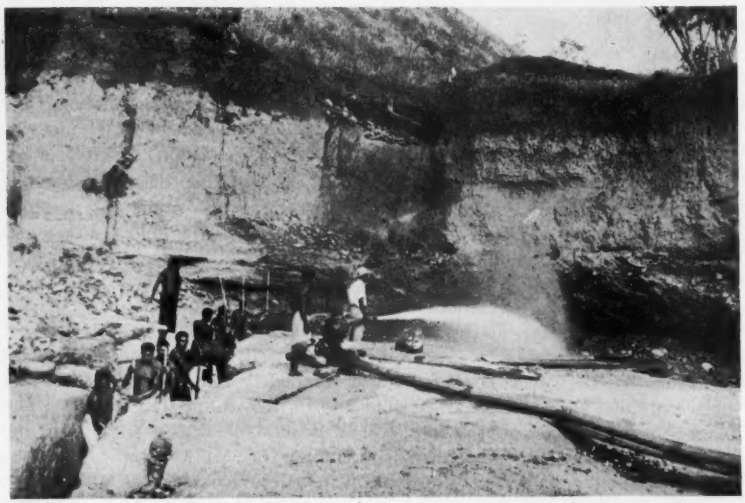
[45] Graton, L. C.: The depth zones of ore deposition. Econ. Geol., vol. 28, no. 6, p. 538, 1933.

[46] Emmons, W. H.: Op. cit., p. 260.

[47] Maclaren, J. M.: Gold, p. 628.

Mesothermal Deposits.

Morobe Goldfield.—The granodioritic gold of the Morobe field has been assigned to the mesothermal stage, mainly on analogy with similar deposits elsewhere, associated with granodioritic batholiths intruded under comparable conditions. Only a few reef occurrences are known, apart from tiny leaders. A small vein of subcommercial grade is exposed on the side of a gully in the Upper Iroa Creek area, Upper Watut River. It is a lenticular vein of ferruginous quartz carrying up to 10 dwts. of gold per ton and is contained in the granite itself, close to the slate contact. The silver/gold ratio is about 50/1, and minerals recognized in the solid quartz portions were galena, pyrite,



W. Chapman's Sluicing Claim, Bulolo. Photo by N. Lishald, Bulolo, T. N. G.

sphalerite, stephanite, hematite and magnetite. Most other occurrences connected with the granodiorite carry a much lower proportion of silver.

Within the Bulolo and Lower Watut valleys the fineness of the gold from the granodiorite areas is remarkably constant, averaging 860 to 890, with a few returns as low as 850 and an occasional one in the Upper Watut or the Upper Bulolo reaching above 900. The following is the list of averages of gold from different creeks shedding from near granodiorite contacts: Kodiak Creek 873.6, Sandy Creek 868.9, Poverty Creek 864.9, Bamboo Creek 868.6, Kulolo Creek 864.2, Black Cat Creek 875.3, Bitoi River 876.0, Iroa Creek 881.1, Surprise Creek 880.4, Roaring Creek 892.8, Subroar Creek 895.0, Bitap Creek 877.1, Waim River 865.9.

New Zealand.—The West Coast magma, New Zealand South Island, active in early Cretaceous times, produced gold 900 to 980 fine. Gold in the

Nelson district, also of Mesozoic age, is upwards of 860, while in Otago and Marlborough, connected with no known igneous rocks, the reef gold, varying in different areas, ranges from 870 to 960 in value, and the derived alluvial 950 to 970.

Queensland.—In Queensland many interesting examples of mesothermal gold lodes have been exploited. At Charters Towers, one of the few rich fields contained entirely in granitic rocks, Reid [48] considers that the gold is probably genetically connected with the magma of the diorite-porphyrite dikes. Lock [49] gives the following figures showing the slighter higher grade of gold in the oxidized ore compared to that of the sulphide zone.

Mine	Oxidized Ore	Sulphide Ore	Difference
St. Patrick	814	767	47
North Australian	860	834	26
Just-in-Time	820	763	57
Queen	823	788	35
Papuan	807	772	35

It is interesting that in the "outside" mines, at a greater distance from the main center of mineralization and characterized by less numerous and less concentrated occurrence of the diorite-porphyrite dikes, the gold is in general of lower and somewhat more variable fineness, namely 660 to 780.

The Mt. Morgan mine is an outstanding example of the refining of gold during the process of oxidation. Exceptional circumstances existed at Mt. Morgan in this respect, as the lode has been twice exposed to the effects of erosion and weathering—in pre-Cretaceous as well as in recent time—with the result that the silver has been almost completely removed from the near-surface ore and some of the purest gold known, 997–8 fine, left behind. The fineness of the primary gold is high, 850 or more.

A most unusual mineral assemblage is found at Mt. Coolon.[50] Zeolites, adularia, chlorite, chalcedonic and banded quartz and finely disseminated pyrite, all are typical, in fact diagnostic, of epithermal conditions. On the other hand epidote, andradite (iron-lime garnet), specular hematite and pyrrhotite are also present and these are equally characteristic of the hypothermal, or at least the lower part of the mesothermal zone. This anomaly could possibly be explained by two stages of mineralization, though no mention of such a possibility is made in the report quoted. The fineness of the gold bullion from amalgamation is 839, from cyanidation 631–671, and the gold and silver content of the sulphide ore, according to the assay of a representative sample, almost exactly equal.

The Cracow goldfield is another that produces evidence of refining by secondary enrichment. The gold in the Golden Plateau surface ore was 970 fine, while that recovered at a later stage in the operations when a fairly big

[48] Reid, J. H.: The Charters Towers Goldfield. Geological Survey of Queensland. Pub. No. 256.

[49] Lock, A. G.: Gold, Its Occurrence and Extraction.

[50] Morton, C. C.: Mt. Coolon Goldfield. Queensland Government Mining Journal, vol. 36, June and July, 1935.

proportion of sulphide ore was being milled ran only 850 fine. Fineness of the gold in the Standard mine was 750. Some of the gangue minerals of the Cracow lodes, such as adularia and the zeolites, together with abundant calcite, and prophylitic alteration of the wallrock, indicate definitely epithermal conditions. Denmead [51] considers it probable that mineralization commenced in the Permo-Carboniferous with injection of the Auburn granite, while later volcanic outbursts in the early Triassic were accompanied by further mineralization. The association of the lodes with volcanic activity is certainly supported by the mineral assemblage and by the conditions of deposition, which appears to have taken place at no very great depth, even though probably at a lower horizon than the typical late Tertiary silver-gold epithermal deposits.

The Croydon goldfield is unique in Queensland, and indeed in Australia, for the low value of its bullion (from amalgamation). The lodes fall into two distinct categories. (1) Lodes in granite. (2) Lodes in felsite. Reid [52] divides the felsite into dikes, varying in composition from feslite to quartz-felspar-porphyry, and graphitic lavas of felsitic type. He considers that the felsite intruded the granite. The reports of North Australia Aerial, Geological and Geophysical Survey [53] refer to the felsite as a volcanic series made up of porphyritic rhyolite, tuff and breccia. Most of the geologists in this survey agree that the granite is intrusive into the felsites. The lodes in granite dip at very low angles, 15–20 degrees, towards the felsite contact, and the lodes in felsite are mostly steeply dipping, though some dip flatly. The Croydon lodes do not contain a wide variety of minerals. Silver-gold ratio is as much as 20/1 in the sulphides but recoveries have averaged about 3/2 in the ore treated, according to the battery and cyanide returns. The lodes in granite especially were characterized by great horizontal extent, but were payable to comparatively shallow depths only, although the lodes persisted to the greatest depths explored. Many of the lodes were not mined below 100 feet vertical depth, few below 300 feet, and the deepest stoping on the field was only 480 feet vertically below the surface. The principal relevant facts concerning the distribution of gold fineness are:

(1) The lodes in the felsite and the lavas contain gold of fairly constant value, between 705 and 820, average 744, though extreme values up to 857 and down to 533 have been recorded, the low values coming mostly from distant lodes. Native silver is rarely present in the felsite lodes.

(2) The lodes in granite carry bullion from 110 to 880 fine, but there is a consistent value, between 520 and 600, average 554, which embraces most of them. The low values, below about 500, come mostly from the Queen of Croydon line of lodes near the granite contact, which carry abundant native silver, and the low bullion values are certainly due to the presence of this native silver.

(3) Bullion values in most lodes in granite decrease with depth. Much

[51] Denmead, A. K.: The Cracow Goldfield. Queensland Government Mining Journal, vol. 39, Oct., Nov., Dec., 1938.

[52] Reid, J. H.: Report on the Croydon Goldfield. Queensland Government Mining Journal, vol. 36, March, April, May, 1935.

[53] Aerial, Geological and Geophysical Survey of Northern Australia, Reports Nos. 16, 23, 25, 26, 38, 51 (Queensland).

of the surface ore, as at Golden Gate, produced gold 650 to 880 fine, whereas gold from the lower levels of the same mines was below 500 fine. This distribution is obviously the result of leaching of silver from the surface ore, leaving the gold relatively enriched, and redeposition of native silver at lower levels.

It is certain that processes of secondary enrichment following on oxidation have operated extensively on the Croydon goldfield; the presence of so much native silver, the absence of alluvial gold, and the decrease in gold fineness downwards are proofs. It is interesting to note that the Croydon lodes, at least those in the granite, furnish one of the few examples of orebodies that have been twice exposed to the effect of surface agencies, with a resultant doubling of the effects of oxidation and secondary enrichment. This is shown by the presence of Cretaceous sandstone overlying the outcrops of part of the lodes, which therefore must have been exposed in pre-Cretaceous time. (It has already been remarked that similar circumstances exist at Mt. Morgan, where also the effects of secondary processes are pronounced.) Furthermore, much of the Croydon field is covered by a lateritic "cap-rock" up to 20 feet thick, showing that the present period of exposure has been of long duration. The Croydon climate consists of a short wet season, usually of only about two months duration, followed by very arid conditions for the remainder of the year.

It is considered that secondary processes are adequate to account for the distribution of the fineness, even the very low bullion values, in the lodes in granite, but in the absence of agreement as to the geological history of the field, it is not possible to put forward a satisfactory explanation of the fundamental difference in fineness of the bullion of the granite lodes from that of the felsite lodes. It is, however, postulated here, on account of the low gold fineness in the granitic lodes and the small vertical range of payable ore, that these lodes at least were deposited under epithermal rather than mesothermal conditions.

Southeastern Australia.—The gold deposits of New South Wales, Victoria and Tasmania are nearly all referred to the mesothermal and nearly all contain high-grade gold. Of fifty-nine districts in New South Wales from which the fineness of alluvial gold has been obtained, all but five average over 900, and these five are all above 850. The fineness of the reef gold may be taken as averaging slightly less.

In the Victorian goldfields, the value of the gold is mostly very high. Both reef and alluvial gold from the main western fields are over 950 fine. Silver minerals are conspicuously absent throughout the State, except at St. Arnaud and Omeo. Gold fineness is generally lower in the eastern half of Victoria, Woods Point reef gold ranging from 769 to 802, though the alluvial goes up to 960. At Omeo the reef gold is only 700 fine and in places less, but the low value is almost certainly due to the presence of native silver in the ore, as the alluvial is 845 to 930 fine.

The gold from nearly all Tasmanian gold-bearing areas is over 900 fine. The average grade of bullion obtained up to 1900 was about 930. The fol-

lowing figures have been furnished by the Acting Government Geologist [54] to show the difference in fineness in the Lefroy district between gold from deep level sulphide ore, from enriched oxidized ore, and from derived alluvials which have been subjected to the refining action of surface waters for a long period. The figures have been calculated to the $\frac{Au}{Au + Ag}$ basis.

Alluvial gold from sub-basaltic lead, 200 feet below the surface	964.6
Battery gold from New Pinafore Reef, surface to 360 feet level	950.0
Battery gold from New Pinafore Reef, 1,100 and 1,200 feet levels	932.3

North America.—Gold in the Appalachian region, extending from Nova Scotia to Alabama, is found mostly in genetic connection with granitic masses intruded in the Paleozoic. In Nova Scotia the fineness is seldom less than 900, but in the Southern Appalachians it may be lower and more variable, in places falling below 800.

The mesothermal gold deposits of Western North America are nearly all associated with the intrusion between late Jurassic and early Tertiary times, of a number of granitic batholiths, the Sierra Nevada and Coast Range batholiths, Boulder batholith, Idaho batholith, etc. Their composition is mostly granodiorite or quartz monzonite. In the vast majority of the deposits the fineness of the gold is between 750 and 900, with rare figures beyond these extremities. The Tenderfoot district in Alaska carries gold 620 to 700 [55] fine but elsewhere it is unusual to find gold, either in lode or alluvial, less than 780 fine. The average of the placer gold of the Fairbanks district, according to Smith,[56] is about 880. In parts of the Yukon field, too, lower grade alluvial gold is found, the variation being from 600 to 820. Maclaren [57] gives the fineness of the gold in some of the principal creeks: Eldorado Creek 765, Bonanza Creek 804, Last Chance Creek 710–735.

The alluvial derived from reefs connected with the Coast Range and Nelson batholiths in British Colombia ranges from about 750 to 870 fine, closely comparable with the Californian and Alaskan deposits of similar origin. The camps listed in the Western United States contain representatives of most of the more important auriferous areas of mesothermal affiliations. Conditions in deposits not listed appear to be similar. The same average value, from about 750 to 900, is maintained remarkably well, considering the many factors which might introduce variations, and this range of fineness may be taken as typical of mesothermal deposits, provided no abnormal features are present. Higher fineness appears to be due to lack of silver or to higher temperature and pressure conditions, whereas lower values, such as Ophir, Cal., 500–700, may result from a variety of causes, but such isolated exceptions do not invalidate the general rule .It is not always possible to classify ore deposits into their different divisions, which in any case constitute a continuous range from the surface downwards, with no definite lines of demarca-

[54] Private communication.

[55] Prindle, L. M.: Geologic Reconnaissance of the Fairbanks Quadrangle, Alaska. Bull. No. 525, U. S. G. S.

[56] Smith, P. S.: The fineness of gold in the Fairbanks District, Alaska. ECON. GEOL., vol. 8, no. 5, 1913.

[57] Maclaren, J. M.: Gold, p. 486.

tion. In places the depths of the various zones are great, at others the whole range is crowded into a very short vertical distance. The zonal classification further assumes that temperature and pressure vary proportionately, but high temperature often occurs with intermediate pressure, and under near-surface conditions moderate to high temperature may be associated with low pressure. Small veins found in a general mesothermal environment may have been formed at low temperature, and the mineral assemblages do not always provide conclusive evidence.

With regard to the veins of the Alleghany district, Cal., which are considered to have been formed at a depth of about 10,000 feet, Ferguson and Gannet [58] say that the fineness of the gold varies from 796 to 869 in individual mines, but that the variation cannot be correlated with any geological or mineralogical factor. In the Mother Lode system the fineness is fairly constant in any given mine. It alters with depth in the zone of oxidation but not below.

In only a few districts has it been possible to obtain the exact silver/gold ratio in the ore but it is obvious that in most cases it is low and rarely are silver minerals present in the gold lodes. The exception is those districts such as Elkhorn, Montana, Coeur d'Alene, Idaho, etc., where the gold is of subsidiary importance, being merely a by-product in the exploitation of large silver-lead-zinc or copper lodes, or derived from alluvial shedding off areas carrying such lodes. It is significant that the gold derived from these typically mesothermal deposits should still be of high value in spite of the presence of abundance of silver. Alluvial gold from Bingham, Utah, derived presumably from the outcrops of copper and silver-lead deposits placed by Lindgren [59] in the pyrometasomatic division, is also of high quality.

Chili.—The gold deposits of Guanaco, Chili, although contained in volcanic rocks, are included in the mesothermal class. Conditions are favorable for surface oxidation and the high fineness, 944, of the gold, which is concentrated by oxidizing processes and confined to near the surface, is almost certainly due to the removal in solution of a large part of whatever silver may have originally been alloyed with the gold. The ores of the Atacama Province appear to be mainly of the mesothermal type and as far as can be ascertained carry gold about 850 fine. Alluvial gold in Chili is usually from 850 to 920 in value.

Hypothermal Deposits.

Australia.—Fineness of gold in this type of deposit is so universally high that it is as a rule taken for granted and many authors make no mention of it. Most of the pre-Cambrian ores fall into this class, partly because of the large amount of erosion necessary to expose them. The West Australian metallogenetic province is a typical example. Most of the mines of South Australia and Central Australia also belong to this division, although fineness as low as $660 \frac{Au}{(Au + Ag)}$ are recorded [60] from Tarcoola, where the average is 825.

[58] Ferguson, H. G., and Gannet, R. W.: Gold quartz veins of the Alleghany District, California. Prof. Paper No. 172, U. S. G. S.

[59] Lindgren, W.: Mineral Deposits, p. 723.

[60] Brown, H. Y. L.: Record of the mines of South Australia, 1908. Government Geologist, S. A. Private communication.

Asia.—A complete set of figures kindly furnished by the Geological Survey of India shows that the gold from Archaean sources is very seldom less than 900 fine. Most important, of course, is the dominant Kolar goldfield. In Siberia and the Ural Mountains gold is mainly derived from hypothermal and mesothermal deposits and is nearly always above 850[61] in fineness.

North America.—The two examples quoted in the table as representing the Appalachian Palaeozoic province of the United States happen to contain gold averaging 850 to 900 fine, deposited under conditions approaching those of the mesothermal zone. Alluvial gold from Georgia averages 928 fine.

The important lodes of Porcupine and Red Lake, Ontario, Noranda, Quebec; Rossland, B. C.; and many others all contain high-grade gold. The famous Homestake orebodies in South Dakota produce gold of a fairly consistent average value. Complete agreement has not been reached regarding the age of mineralization, whether pre-Cambrian, Tertiary or both. Paige considers it probable that the main mineralization took place in pre-Cambrian times under hypothermal conditions, and that probably enrichment occurred in the Tertiary. The fineness of the gold, 835, is rather lower than in most hypothermal deposits. On the other hand it is more consistent than would be expected if two generations of gold mineralization were present. Not much silver is present in the ore, as cyanide bullion assays just under 700 fine. Interesting details on the gold fineness in the Homestake mines are given by Sharwood,[62] showing that the fineness does not perceptibly increase with depth; in fact the surface workings return the lowest grade of gold. When separated into fractions according to grain size, the fineness shows a definite decrease in the smaller grains. This decrease is less marked when calculated as $\frac{Au}{Au + Ag}$, and is largely due to an increase in base metal content, which may be caused by mechanical admixture of very fine grains of pyrite and other minerals for the values are based on pannings, and it is very difficult even with mercury to ensure complete separation of gold, from pyrite particularly. (A similar increase in purity of gold with grain size has also been noticed in other gold deposits. Variations in temperature at the time of deposition may be capable of explaining these differences in the case of primary ore for the presence of large grains or crystals of gold suggests higher and more uniform temperature—with resultant higher fineness—for their formation than would be expected for fine grains.) Sharwood's results are reproduced in the following table.

South America.—The alluvial gold of El Callao is 915 fine, similar to that elsewhere in the Guayana Highlands of Venezuela, so it is assumed that the lode gold is not much lower in value. The range in alluvial gold throughout Venezuela is 850–960.

The Morro Velho is referred to by Lindgren and Graton as a typical hypothermal deposit. It shows little change in character throughout the great depth mined. Maclaren gives the fineness of the bullion obtained as 790–810

[61] Phillips, J. A.: Mining and Metallurgy of Gold and Silver.

[62] Sharwood, W. J.: Analyses of some rocks and minerals from the Homestake Mine, Lead, South Dakota. ECON. GEOL., vol. 6, no. 8, 1911.

TABLE 5.

FINENESS OF GOLD IN THE HOMESTAKE MINE

Part of Mine	Grain Size of the Gold	Gold Fineness	Silver Fineness	Base Content	Au / Au+Ag
Surface workings	Coarse	831	169	—	831
	Medium (on 100 mesh)	823	177	—	823
	Fine (through 100 mesh)	819.5	176.2	4.3	823
400, 500 and 600 ft. levels	Coarse	849	151	—	849
	Medium (on 50 mesh)	832	163	5	836.2
	Medium (on 100 mesh)	829	163	8	835.7
	Fine (through 100 mesh)	823	173.3	3.7	826
700, 800 and 900 ft. levels	Coarse	849.5	150	.5	849.9
	Medium (on 100 mesh)	834	160.7	5.3	838.4
	Fine (through 100 mesh)	830	167.5	2.5	832.6
1000 ft. and deeper levels	Coarse	841	158	1.0	841.8
	Medium (on 100 mesh)	834	159.3	6.7	839.6
	Fine (through 100 mesh)	823	166.8	10.2	831.5
Average all above		835	161	4	838.4
Average one week's panning, all parts of mine	Very coarse, 20–40 mg.	839.5	157.8	2.7	841.8
	Coarse, 5–10 mg.	840.0	151	9.0	847.6
	Medium (on 100 mesh)	825.5	172	2.5	827.6
	Fine (100–200 mesh)	813.5	164	21.8	832.2
	Very fine (through 200)	797.0	161	42.0	831.9

but he does not make it clear whether it represents the true fineness of the gold, or that of the gold bullion as recovered by whatever process is in use. Alluvial from the Minas Geraes district, though not necessarily derived from the Morro Velho outcrop, is 920–940 fine. The bullion from the Passagem orebody, also formed under hypothermal conditions, is 940 to 960 in value.

Pyrometasomatic Deposits.—The Cable mine, Montana, and the deposits of Bingham, Utah, belong to Lindgren's pyrometasomatic division, which is on very logical reasoning included by Graton within the hypothermal class. The Cable mine carries very high grade gold, and the alluvial derived from the vicinity of the immense copper and silver-lead deposits of Bingham is also in excess of 850 parts per thousand.

GENERAL CONSIDERATIONS.

Considering the epithermal deposits first, the fineness of the gold is seen to range mostly from about 500 to 750, with a few isolated instances showing a much higher grade of gold. In general in this discussion fineness values from below 500 up to 700 are referred to as low, 700 to 800 medium, and above 800 high. (The theory has been put forward that gold and silver combine together in certain definite proportions, as AuAg, Au_2Ag, etc., but this idea has not met with general acceptance. In any case it has little bearing on the actual gold occurrence, which ranges continuously in fineness from below 500 to almost pure, so that if chemical compounds are present they exist in an infinite variety of mixtures.)

Reference to Table 5 shows that all those occurrences containing gold of the lowest range of fineness, 500 to 600, are also of the very latest age, mostly post-Miocene, and nearly all the rest of the epithermal division belong to the later half of the Tertiary period. In almost every case the fineness of the gold is less than 800, except in those specially mentioned previously. The generalization can equally well be made that the mesothermal deposits carry gold rarely less than 800 fine; most of them belong to the early Tertiary or Mesozoic periods, those of the Australian Palaeozoic metallogenetic epoch constituting a notable exception; and nearly all are associated with granitic or granodioritic intrusives. Most of the true hypothermal deposits are of pre-Cambrian age and high gold fineness. Here is a clear-cut association of different grades of gold with different ages of mineralization and different depths of deposition, and in general the older the deposit and the greater the depth, the finer the gold. It is also noticeable that the epithermal gold lodes usually have a high silver content, the mesothermal seldom and the hypothermal very rarely. It seems clear that there can be no necessary connection between the gold fineness, or the gold/silver ratio, and the age. It is not reasonable to assume that, for instance, pre-Cambrian magmas carried practically no silver, Mesozoic and early Tertiary magmas a little, and late Tertiary ones a preponderance of silver. Besides, the occurrence of the numerous older silver-bearing deposits, some of them derived from the same magmas as payable gold lodes, as the Nelson Batholith, B. C., to quote only one instance, shows quite definitely that the earlier magmas were far from devoid of silver. Moreover, many epithermal deposits particularly deposited under similar conditions, may contain only about equal amounts of gold and silver, *e.g.,* National, Manhattan; or a silver/gold ratio of up to 100/1 or more as at Tonopah, Silver City, and Comstock; and yet give the same grade of gold. Consequently the availability of silver to alloy with the gold can not be regarded as the fundamental cause of variation in gold fineness. On the other hand the table does show a direct relationship between the depth of deposition from the surface, with corresponding variation in temperature and pressure, and the gold fineness, and therefore the variation in depth must be considered as the essential cause of the general differences in gold fineness. This cause is capable in itself of explaining the correspondence of the different finenesses with the age of mineralization. For probably epithermal gold ores were formed in pre-Cambrian and later times, but there is little chance that lodes formed so close to the surface could have escaped, throughout such long time intervals, the destructive effects of erosion. Maclaren [63] assumes that the gold of the older deposits has been refined by selective agents of solution and reprecipitation or else its high fineness denotes a long journey in space through fissures in rock capable of exercising a selective action on the metals of passing solutions. The general uniformity of gold fineness in any one vein, apart from oxidation effects, is an argument against both these assumptions, and even in pre-Cambrian deposits there is little opportunity for solution and reprecipitation of the gold until it is exposed to the action of vadose waters, and this seldom happens more than once in the history of any given orebody. The theory

[63] Maclaren, J. M.: Gold, p. 24.

that the wall rocks should selectively precipitate the metallic content is more acceptable, though the tendency would be for gold, on account of its relative insolubility, to be precipitated first, so that high fineness would denote the reverse of a long journey through space. Palmer and Bastin [64] have shown that nearly every mineral which will precipitate gold will also precipitate silver except galena, pyrite, stibnite and millerite. Undoubtedly in special circumstances the nature of the wall rock or of previously formed minerals may exercise a strong influence on the precipitation of the gold, but it is unreasonable to assume that these special chemical conditions should always be present at great depths, nor do the field facts support such an assumption. There is no doubt that solutions depositing gold in many of the older deposits also carried abundant silver, so the increase in fineness with depth strongly indicates that temperature and/or pressure and not the nature of the wall rock was the dominating factor in determining the amount of silver alloyed with the gold.

Another cause which might be expected to affect the gold fineness would be the composition of the magma from which the lode material was derived. Table 5 shows that in the great majority of instances the associated magma is andesitic or granodioritic, which are practically equivalent. It has not been possible to trace any relation between the fineness and the composition of the associated igneous intrusives.

In his description of the Jarbridge district Schrader [65] states that the East vein system occurs at a geologic horizon 2,000 feet or so above the West vein system, that the East veins may possibly be younger, and that the fineness of their gold is much lower than in the West veins. With regard to the National Mine, Lindgren [66] records that some authorities maintain that the gold nearer the surface is of lower grade, $9 per ounce (435), than in depth, $11 per ounce (532). In the Oatman district,[67] Arizona, five stages of vein filling have been recognized, with the proportion of silver to gold successively decreasing from 6/1 to 1/4. In a description of the Boise district, Idaho, Lindgren [68] lists four mines occurring at a distance from the porphyritic dikes, with gold fineness varying from 680 to 770, and two mines close to the dikes with a gold fineness 825 to 870. In the Blue Mountains region of Oregon, Hewett [69] recognizes a zoning of the ores around the Bald Hill Batholith: (1) an inner zone with pyrite and arsenopyrite and little free gold; (2) a zone in which pyrite and arsenopyrite are prominent and galena and free gold are more abnuant; (3) an outer more productive zone in which the lodes carry less iron sulphides, but more tetrahedrite, silver minerals and free gold. The fineness of the gold in at least some of the mines of this outer zone, *e.g.*, North Pole, is only 500–600.

[64] Palmer, G., and Bastin, E. S.: Precipitants of gold and silver. Econ. Geol., vol. 8, 1913.
[65] Schrader, F. C.: The Jarbridge Mining District, Nevada. Bull. No. 741, U. S. G. S.
[66] Lindgren, W.: Geology and mineral resources of National Mining District, Nevada. Bull. No. 601, U. S. G. S.
[67] Lindgren, W.: The mining districts of the Idaho Basin and the Boise Ridge, Idaho. 18th Annual Report, U. S. G. S.
[68] Hewett, D. F.: Am. Inst. Min. Eng. Trans., vol. 96, pp. 305–346, 1931.
[69] Lausen, C.: Geology and ore deposits of the Oatman and Katherine Districts, Arizona. Bull. No. 131, Geol. Series, No. 6, Arizona Bureau of Mines.

All these occurrences confirm that where suitable ore channels are present the solutions tend to carry the silver farther afield than the gold, presumably to regions of lower temperature, so that gold deposited nearer the source will be of higher fineness, and gold of lower fineness will be found with other silver minerals farther away, that is, usually at a higher horizon.

The extreme variation in the silver/gold ratio shows that the concentration of silver has but little effect on the gold fineness, and that provided sufficient silver is present, the gold and silver will be deposited in the proportions appropriate to the physical conditions prevailing. The bullion thus naturally formed is never below about 450 fine, the remainder of the silver going to form other minerals, while if sufficient silver to produce the requisite proportions is not present, the fineness of the gold will of course be higher, as at Goldfield, Nevada.

The question of the silver/gold ratio and the fineness of gold in ore deposits formed at different depths is naturally bound up with the conception of zoning, which as far as gold is concerned is complicated by its appearance at two principal places in the series, one at depth and one near the surface. Silver similarly occurs more than once, usually farther from the source than the gold. The magmatic origin of epithermal deposits is regarded by Lindgren [70] to be even deeper than that of mesothermal and hypothermal ores, while other geologists place it shallower. Graton's [71] view that the depth of the magmatic source is similar, or at least varies within the same range, for all three types, is the most reasonable. In any case epithermal ores are deposited so far from their source that its direct influence must be negligible, and Lindgren states that no zonal arrangement is apparent in them, except a common impoverishment in depth. This feature is very logically explained by Graton as due to the normal change from dominantly precious metal to dominantly base metal ores in depth, but owing to the higher concentration required of base metals to be payable, the zone where the precious metal values cease usually marks the bottom limit of exploitation. He quotes Casapalca, Peru, as an exception, in which the base metal content of the leptothermal ores underlying the epithermal silver lodes is sufficient to allow their continuous development, with silver as a by-product. Is it reasonable then to assume that at much greater depths high temperature and pressure gold deposits might be formed, not necessarily in the same lode but deposited from solutions originating from the same magma? Take for example the pre-Cambrian hypothermal gold deposits. Did the solutions emanating from these magmas form gold lodes under hypothermal conditions with gold of high fineness due to the reluctance of silver to be deposited in such an environment, regardless of the presence of possible precipitants, and, migrating farther from the source, eventually follow channels opened for them by co-magmatic volcanic extrusives and deposit epithermal ores near the surface, exactly as in the case of the late Tertiary epithermal lodes? This seems reasonable to assume, and probably applies as well to Palaeozoic and Mesozoic magmas associated with hypothermal or mesothermal gold deposits. For if erosion has reached the stage where

[70] Lindgren, W.: Mineral Deposits, p. 455.
[71] Graton, L. C.: The depth zones in ore deposition. ECON. GEOL., vol. 28, no. 6.

the deeper deposits are exposed for exploitation, it follows that the epithermal ores formed by the same magma have long since been removed by denudation. Similarly higher temperature lodes have undoubtedly been formed at depths by the earlier stages of the solutions emanating from the magmas which produced the Tertiary near-surface deposits, but erosion has in very few instances been able to expose them. Some of the Tertiary mesothermal and hypothermal lodes of the Andes region in South America are exceptions. So, although within epithermal deposits little zonal arrangement may exist, they themselves are an expression of the zonal arrangement relative to the magmatic source.

An important factor in determining whether the gold and silver will be deposited close to or at a distance from the magma will be the presence of channels along which the solutions can travel; hence the association of the epithermal deposits with volcanic rocks or minor intrusives, since where lavas can ascend from the magmatic chamber to the surface, ore-bearing solutions can also. Tectonic conditions at the time of magmatic intrusion may thus affect the types of ore deposited, for if fracturing of the crust encourages the outpouring of volcanic material and the intrusion of dikes, the usual condition during epochs of igneous intrusion, many passages will be available for ore solutions to travel upwards. On the other hand if a magma pushes and stopes its way up quietly in a period of tectonic calm, ore deposits will be formed deep below the surface in close proximity to the intrusive, wherever deposition is possible, as in the Early Tertiary epoch of mineralization in the Cordilleran region of the United States. In these deeper formations, even where silver is abundant, the gold is deposited comparatively pure, while near the surface, so long as sufficient silver is available, a low grade alloy with a minimum fineness not much below 500 will be formed, and intermediate grades of gold at intermediate depths, often varying with local factors such as the composition of the wall rocks, the character of the minerals deposited earlier, the presence or absence of silver in the solutions, and many other factors, but, other things being equal, showing a general dependence upon temperature and pressure, particularly temperature. It has been noted earlier that the temperature is not always a direct function of the depth below the surface, and deposits formed at intermediate or even at shallow depths may have been associated with much higher temperatures than is the rule at that horizon, and even at considerable depth lodes may have been formed at low temperatures by solutions that have migrated a long way from the magma from which they have been derived. These considerations introduce a further source of variation of gold fineness, but from the foregoing discussion it is clear that the fineness of the gold in any lode must be included in the list of criteria diagnostic of depth of deposition and of the temperature at which the lode was formed, but like every other individual one of those criteria, it must be considered with cautious regard for other possible factors of variance, such as those enumerated above and, in addition, alterations which may be due to oxidation.

RESUMÉ.

The subject of the relation of gold fineness to the conditions of deposition requires much further detailed research into the distribution of gold fineness

in a number of representative fields, which probably could be done only by personal investigation, and also lends itself to laboratory experimentation on the composition of gold deposited from gold-silver solutions of different concentrations and at different temperatures. In the absence of such facilities the following list of conclusions to which the present investigation has led are presented, with the hope that discussion and criticism may thereby be stimulated, and that other geologists working on deposits of gold ore may be encouraged to study more closely and to record the details of gold fineness distribution.

1. Fineness of gold shows a general increase with depth of deposition, which implies high temperature and pressure, and appears to be correlated more closely with temperature.

2. Vein gold varies in fineness from about 450 up to 999 in oxidized ore. Lower bullion values from amalgamation processes are due to the presence of native silver, *e.g.,* Croydon, Queensland.

3. Hypothermal deposits always contain high-grade gold which has a lower fineness limit of 800, but is usually higher, *e.g.,* Kalgoorlie, Kolar, and Minas Geraes.

4. Gold in deposits of the mesothermal zone is typically 750 to 900 fine, but often higher, *e.g.,* Ballarat and Bendigo. Lower values occasionally occur, *e.g.,* Tenderfoot, Alaska, and Ophir, California, but investigation would probably reveal that these are due to special chemical or physical conditions.

5. Gold in epithermal deposits ranges usually from 500 to 800. In recent veins formed near the surface it is mostly about 500 fine, *e.g.,* De Lamar, Idaho; Edie Creek, New Guinea; in Miocene and earlier veins seldom less than 600, *e.g.,* Waihi, New Zealand. Those deposits whose mineral composition and other characteristics suggest deposition towards the bottom of the epithermal zone contain gold more than 700 fine, *e.g.,* Lower Edie, New Guinea; Camp Bird, Colorado.

6. Under any given set of conditions gold fineness tends to be constant, particularly in deposits connected with the same intrusive batholith, *e.g.,* Morobe, New Guinea; Sierra Nevada, Western America. Wide variations may occur, however, in ores connected with the same intrusion but formed under different physical conditions, *e.g.,* Blue Mountains, Oregon.

7. Gold in the oxidized zone is nearly always higher in grade than the primary gold, and this difference varies largely according to chemical conditions and the facilities that exist for removal of the silver in solution, the gold being redeposited close by, or merely left enriched by the removal of the silver. Under conditions suitable for taking gold into solution, the gold redeposited, if the concentration of silver remains high, will not necessarily be of high fineness.

8. Very high gold fineness is usually the result of oxidation under conditions favorable for the complete removal of silver, *e.g.,* Mt. Morgan, Queensland. High fineness is often associated with the oxidation of telluride ores, *e.g.,* Fiji; Cripple Creek, Colorado.

9. Alluvial gold, being derived from the oxidized ore, is of higher quality than the average of the vein gold, and shows an increase in value downstream, due to surface refining action, as the size of the grains decreases.

10. The concentration of silver as shown by the silver/gold ratio has little effect upon the fineness of gold except where insufficient silver is present to alloy with the gold in the proportions requisite to the physical conditions, *e.g.*, Goldfield, Nevada.

11. In the deeper zones, that is, at higher temperature and pressure, silver, no matter how concentrated in the ore-bearing solutions, will not form a low-grade alloy with gold, but is deposited as other primary silver or silver-bearing minerals.

12. Tellurium, if present, will combine with gold and silver in proportions appropriate to the relative concentrations, *i.e.*, calaverite, the gold telluride, will tend to form in regions like Cripple Creek and Kalgoorlie where the silver content of the ore is low. Gold seems to have a greater affinity for tellurium than for silver. If excess gold and silver are still present after all the tellurium has been taken into combination as tellurides, they will alloy together in the proportions typical of the environment, *e.g.*, Kracs-Czebe, Transylvania.

PRACTICAL APPLICATIONS.

It has been shown that for the Morobe goldfield, by comparing the average fineness of the gold in two streams with that below their junction, it is possible to calculate the relative amounts contributed by each of them, as with the Bulolo and Watut Rivers, or Wau and Sandy Creeks. The value of this from the prospecting point of view is obvious, as it gives a quantitative basis for assessing the importance of the various tributaries and serves as a guide for further prospecting. It has also been shown for the Morobe field how the alluvial history of many of the stream deposits can be inferred from the fineness of their gold, which at once gives a clue to its origin and to the drainage conditions prevailing at that time. Sudden considerable changes in the fineness reveal the presence of important new sheds of gold, such as the Lower Edie, and indicate likely areas to prospect for lode formations. Small local increases on the Morobe field are generally caused by the addition of gold from creeks shedding off granodioritic sources, such as Subroar Creek and Bitap Creek in the Lower Watus area, while decreases in fineness like that experienced in the Bulolo River after passing the mouth of the Koranga show that a shed of low-grade gold has been tapped. In an area like the Morobe goldfield where the fineness of the gold associated with each type of intrusive has been well established, the value of the gold gives the prospector and the geologist an important lead towards its source and indicates the type of country to be expected in association with it, and the nature of the deposit to be looked for.

The geological implications of the fineness of the gold are many. Its distribution, where several different values are present, acts as a guide-book to recent erosional history, and within the limited area for which constant conditions have been established, it furnishes valuable information of the geology. For instance, it was possible, from a knowledge of the distribution of the gold in the Waria River area, New Guinea, and its fineness, to forecast with some accuracy the essential features of the economic geology of that district and of the distribution of igneous intrusives. The usefulness of the gold fineness in

an orebody in determining the conditions of its formation has been indicated in the foregoing sections. Variations in the quality of the gold within lodes are not thoroughly understood, and may be very different under different conditions, but a detailed study of the fineness of the gold at various levels should furnish useful data with regard to the amount of leaching and secondary enrichment that has taken place and may be of value in determining the possible extension in depth of the orebody. Since this paper was first started (in 1940) R. A. Mackay [72] has published an account of the relation between secondary enrichment and gold fineness in a number of mines in Tanganyika and Nigeria which illustrates remarkably well some of the possible results of a study of gold fineness distribution.

ACKNOWLEDGMENTS.

In conclusion the writer wishes to record his indebtedness to New Guinea Goldfields Limited for supplying data on gold fineness not otherwise accessible, and for their ready cooperation at all times; to Mr. L. C. Noakes for assistance in various geological problems, and to the many miners of the Morobe and other districts, whose neverfailing hospitality does much to alleviate the arduousness of field work on New Guinea's mountainous mainland; to the Directors of the various Geological Surveys, particularly of the Australian States and New Zealand, for providing information on gold fineness and the geological conditions under which the various ore deposits were formed; and to the Geology Department of the University of Queensland, and to the Geological Surveys of Queensland and of the Netherlands East Indies, for the generous use of their libraries.

MINERAL RESOURCES SURVEY,
CANBERRA, AUSTRALIA,
Sept. 15, 1945.

[72] Mackay, R. A., The purity of native gold as a criterion in secondary enrichment. ECON. GEOL., vol. 39, no. 1, 1944.

EDITORIAL

NEW INTERNATIONAL MINERAL PROBLEMS.

The emergence from war brings forth many new national and international problems within the domain of the mineral field. As in the case of industrial reconversion there lie ahead necessary readjustments in the mineral industry. Geologists engaged in war activities are now returning to their former pursuits, many of them enriched with the knowledge and experience gained through the necessities of wartime operations; many have mastered new procedures and techniques; others are returning to pick up where their work was interrupted; all have gained a broadened outlook.

Mining companies, too, are beginning to take stock of their positions. They view with dismay the wartime depletions of their ore reserves from which, in many cases, there will be no recovery. They plan with caution the extent to which they may be justified in increasing development and exploration at higher ratios to ore production than was formerly the prudent procedure. They are looking farther afield to find replacements for those reserves they so unstintingly yielded up during the stress of war. American companies feel no complacence in the fact that within the United States, even under the impelling demand for war minerals that resulted in high prices and widespread and expensive exploration, little was revealed by way of new reserves or new large deposits. They have reluctantly come to the conclusion that the United States in the future can no longer be so self-supporting in minerals as in the past and that they must look elsewhere, singly, or in conjunction with others, to find the supplies necessary for our economy. They feel uncertainty or distrust in the national leadership that is necessary to instill confidence in order that mining programs may be laid out involving large expenditures over considerable periods of time. They see vagueness with little indication of immediate clarification in the course that our government may pursue with respect to international ventures. Moreover, they fear the future foreign market outlook and the ability to be paid in acceptable exchange for products they may desire to sell abroad. They realize that two former large consuming countries of minerals and mineral products cannot for a long period of time, if ever, be large importers of the basic ingredients of modern industry. They are also just beginning to realize that for the replacement of exhausted reserves every art of technical and scientific ore-finding must be utilized, and new ones must be developed.

The exhaustion of ore reserves during this war has not been confined to the United States alone. Other countries likewise are facing the same problems. The metallurgical chrome of New Caledonia is largely of the past and that of Rhodesia has suffered inroads that spell depletion much more rapidly

than was ever anticipated. Bolivia has basis for real worry as to the future outlook of its tin-mining industry. Lead and mercury in Mexico can hardly regain or retain their pre-war or war-time eminence. The easily found corundum of South Africa has gone the way of our high-grade bauxite, and its commercial chemical chrome has suffered serious inroads. The beryl of Argentina is now of the past tense and the Belgian Congo faces diminished tin output. The high-grade vanadium ores of Peru have passed their heyday and the economically extractable tungsten of Bolivia and Argentina will sink to low levels of production under normal prices. China, apparently, among the United Nations, has suffered the least depletion of its mineral reserves and has awakened to the realization that its deposits may be made to supply a greater share of world demand than formerly. Most nations, therefore, share alike the problems of depleted mineral reserves, but few outside of the United States face production output below their own needs.

If, then, amongst the world of nations some desire to acquire and others to develop and dispose of their minerals, international relations should have the objective of as free intercourse in minerals as possible, with trade barriers held to a minimum. There is a tendency today among several countries to impose barriers that restrict development and exportation of their minerals. This comes at a time when those same countries are exerting themselves to increase their foreign exchange in order that they may purchase more of those necessities of which they were deprived during the war. There is an understandable attempt among them to build up their own consumption and manufacture of their mineral output rather than to export the unmanufactured raw materials. Such attempts, however, have not so far proved entirely satisfactory. When Brazil, for example, by unilateral decree imposed an unusually high export price upon beryl and tantalite, and provided further that a one hundred percent payment should be made in Brazil based upon Brazilian weights and analyses, they promptly lost the United States market, and spurred development in India to meet United States demands. Now the Brazilian area resembles a Western ghost mining camp. Likewise the governmental fixing of artificial and unreal currency exchanges is prohibiting the purchases of minerals in North Africa and Madagascar. The imposition of high export taxes brings similar results. These are features that need careful study in mineral producing countries if the mining industry is to flourish and international mineral trade is to prosper.

A different situation exists with respect to copper. United States requirements during reconversion are running at a higher rate than domestic production, although when manpower increases and development is caught up, post-reconversion demand and supply will probably about balance. In copper producing countries outside of the United States, however, production capacity is greatly in excess of present world demand. Total demand outside of the United States is abnormally restricted and will continue to be less than pre-war for some time to come. Consequently, curtailment of copper mining in those countries is inevitable, and such curtailment is at the expense of exports since their domestic consumption is small. This brings about a decrease in national revenue and entrains hardships and oftentimes tragic economic ad-

justments. This is more particularly the case in those countries, such as Chile, where a major part of the national income is derived from the copper mining industry. It means that careful forward planning and adjustment has to take place. Precipitate action by any one country may bright about a world crisis in copper mining.

In the case of tin, also, a strained situation exists with a world demand currently in excess of supply and the largest market in the United States. When Far Eastern mining and smelting is rehabilitated the productive world capacity will probably again exceed world demand, and restriction in output will once more become necessary. Which country or countries will carry the burden of restriction?

Does it not mean in the case of copper and tin, and perhaps also with other metals and minerals, that some form of international agreement is desirable or necessary? Considerable thought already has been given to this question, but delayed action may necessitate commitments in advance of any international arrangements.

These are but a few of the postwar problems that now face the mining and geological fraternities.

ALAN M. BATEMAN.

WAR AND POSTWAR CHANGES IN THIS JOURNAL.

This JOURNAL has just emerged from a second war period and our readers will have observed that certain changes were necessitated by wartime conditions. The Editor has been absent on war duties since early in 1942, and during the last two years the editorial duties have been carried largely by Mr. William Burns, as Assistant Editor, and by members of the Board of Associate Editors. To each of these our subscribers and our officers are deeply thankful.

The subscription lists naturally suffered a falling off, and our income fell off accordingly. This was particularly true of the foreign subscriptions. In view of the drastic reduction in foreign mailing facilities it is surprising that the foreign subscriptions have kept up even as large as they now are. Japan, Germany and Russia were among the five largest foreign subscribing countries prior to the war. Many foreign subscriptions, however, were maintained during the war with requests that the numbers be held up until mailing facilities were reinstated. This has been done and such back numbers are now going forward.

Based upon the experience gained after World War I, the JOURNAL undertook the financial risk during World War II of printing a considerably larger number of copies of each issue than was justified by the size of the current subscription list. This was done in order that those whose subscriptions were broken could later purchase the back numbers and so maintain a complete file. This was an obligation we felt we owed to our subscribers even though the JOURNAL may have to suffer a loss by not being able to sell all of the extra volumes that were printed. The JOURNAL will endeavor to

supply requested back issues in whole volumes in preference to individual numbers in order that an individual volume may not become broken by the lack of a single number to fill it.

The reduction in size of the JOURNAL during the war has been occasioned by three factors: one, the amount of paper permitted by the government for each volume (including reprints); two, a change in format with a slight reduction in size of type face and a larger type page; and three, a shortage of manuscripts during a certain period. The largest factor is the change in format, by means of which 100 pages of the present text contain the same number of words as 156 pages of the former text. Although the restriction on the amount of paper that may be used is now lifted, paper is still difficult to obtain as desired. As soon as this can be overcome the JOURNAL will return to its normal number of words per number. With the expected change in availability of paper there should also be less delay in the publication time of articles. The Editor will then be in a position to welcome desirable articles, discussions and reviews.

THE EDITOR.

DISCUSSION AND COMMUNICATIONS

MINOR ELEMENTS IN SPHALERITES FROM BELGIUM.

Sir:—I was much interested in Warren and Thompson's valuable paper published in the August, 1945, number of this Journal, and desire to supplement that paper by a study of the spectrographic characters of the metallogenetic Meuse-Vesdre province, which contains numerous veins of téléthermal mineralization: marcasite-galena-sphalerite. Selective association of minor elements with sulphides is indicated. This fact enlarges the problem of "impurities" included in minerals.

In 1942, I examined a similar problem dealing with the minor elements in sphalerites that originate in different deposits in Belgium, of which only one is now productive, namely, Vedrin, in the Province of Namur, 3 miles north of Namur.

The mineralization belongs to the téléthermal type, *i.e.*, marcasite-galena-sphalerite-sulphides in radial faults in Carboniferous limestone and dolomite horizons in the northern belt of the "Namur Syncline." They appear along the Meuse and Vesdre Valleys and continue into Germany, in the area of Aachen and Stolberg. The purpose of this spectrographic study of sulphides from Moresnet, Engis and Vedrin regions is to establish the criteria of the Meuse-Vesdre metallogenetic province. Quantitative results are lacking but the qualitative data seem of interest since new phenomena appeared in the relations between sulphides and minor elements associated with them.

Origin of Samples.—Thirty-one samples were chosen from Schmalgraf, Moresnet, Bleyberg, Les Awirs, Engis, Le Dos, La Mallieue, Corphalie and Vedrin. Among them are sphalerite, galena and marcasite, which have been analyzed after being sorted, separated and powdered.

Results of Analyses.—About thirty elements were determined in each sample (Table I).[1] The metals or metalloids absent or present in very weak traces are: Bi, Sb, Ga, In, As, Te, Mo, Cr, Va, W, Hg, Ph, Ba, Sr, Bo, Pt, Ir, Ti, Re, Tl. No valuable conclusions can be based on these elements. Likewise the relations are of little meaning for Sn, Ni and Co, which are sometimes present.

Elements Regularly Present.—Iron is found in every sample, either in included marcasite or as a chemical constituent of the sphalerite. All of the sphalerite contains iron.

Copper is everywhere. Its amount, however, seems to lessen in the samples from Moresnet-Engis to Vedrin, or from East to West. Its pro-

[1] The different spectra were obtained on a Gevaert Graphic Contrast plate, anti-halo, 220 H & D or 14–15° Sch., with the Zeiss Spectrograph (Qu. 24) which had a useful range from 2,200 to 5,000 A.

Each sample powder was placed on the lower or positive electrode made of graphite of highest purity.

TABLE I.

Nature of samples (Origin)	Mn	Fe	Cu	Pt	Ag	Sn	Bi	Sb	Cd	Ga	Ge	In	As	Te	Co	Ni	Mo	Cr	Va	Tu	Hg	Si	P	Al	Ba	Sr	Ti	Mg	Bo	Pr	Ir	Tl	Ca	Re	Zn	Dis-trict of	Nature of samples
White lithoidal sphalerite (Moresnet) *	tr	3+	2+	4+	–	5+	tftr	–	3+	ftr	+	–	ftr		–	–						1+		2+				2+	ftr			tr	1+	–	TF		
Yellowish sphalerite (Moresnet)	–	+	–	+	+	–	–	–	+	–	+	–	–		–	–						+	f	–	–			+	–	–	–	ftr	+		TF	Moresnet	
Brown sphalerite (Schmalgraf)	tf	+	+	+	+	–	–	–	+	–	+	–	–		–	–						+	–	–	tr			+	–	–	–	tr	+		TF		
Brown sphalerite (Bleyberg) *	tr	3+	5+	2+	2+	5+	tr	tr	3+	+	ftr	tr	ftr		tftr	–						5+		1+				3+	tftr			tr	2+	tr	TF		
— — — —	–	–	–	–	–	–	–	–	–	–	+	–	–		F	F						+		+				+	–			tr	+		TF		
Brown sphalerite (Les Awi 8)	+	+	+	+	+	+	–	–	+	–	+	–	–		–	–						+		+				+	–			tr	+		TF		
Yellowish sphalerite (Les Awirs)	–	+	+	f	+	f	–	–	+	–	+	–	–		–	+						+		+				+	–			tr	+		TF		
Dark sphalerite (Les Awi 8)	+	+	+	+	+	tr	–	–	+	–	+	–	–		tr	tr						+		+				+	–			tr	+		TF		
Dark sphalerite (Les Awirs)	+	+	+	f	+	tr	–	–	+	–	+	–	–		tr	f						+		+				+	–			tr	+		TF		
Yellowish sphalerite (Engis)	+	+	+	f	+	f	–	–	+	–	+	–	–		–	–						+		+				+	–			tr	+		TF	Engis	Sphalerites
Yellowish sphalerite (Engis)	+	+	+	f	+	+	–	–	+	–	+	–	–		f	+						+		+				+	–			ftr	+		TF		
Yellowish sphalerite (Engis)	+	+	+	+	+	+	–	–	+	–	+	–	–		–	tftr						5+		tr				2+	tftr			ftr	1+	tftr	TF		
White galactitical sphalerite (Engis) *	tftr	3+	5+	3+	5+	–	tftr	–	3+	tr	+	–	ftr		–	tftr						3+		3+				3+	ftr			ftr	4+	tftr	TF		
Botroidal white sphalerite (Engis) *	+	3+	5+	4+	2+	–	tftr	–	3+	tr	2+	–	ftr		–	tftr						–		+				+	–			tr	+		TF		
Light yellow sphalerite (Doe)	+	+	+	+	+	–	–	–	+	–	+	–	–		–	–						+		+				+	–			tr	+		TF		
Brown sphalerite and pink calcite (La Mallieue)	+	+	+	+	+	–	–	–	+	–	+	–	–		–	–						+		+				+	–			tr	+		TF		
Light yellow sphalerite (Corphalie)	+	+	+	+	+	–	–	–	+	–	+	–	–		–	–						+		+				+	–			tr	+		TF		
Light yellow sphalerite (Corphalie)	+	+	+	+	+	–	–	–	+	–	+	–	–		f	+						+		+				+	–			tr	+		TF		
— — — —	–	–	–	–	–	–	–	–	–	–	–	–	–		–	–						–		f				–	–			–	–		–		
Brown sphalerite (Vedrin)	+	+	+	+	+	+	f	–	+	+	–	+	–		–	–						–		–				+	–			tr	+		TF		

TABLE I—*Continued.*

Nature of samples (Origin)	Mn	Fe	Cu	Pl	Ag	Sn	Bi	Sb	Cd	Ga	Ge	In	As	Te	Co	Ni	Mo	Cr	Va	Tu	Hg	Si	P	Al	Ba	Sr	Ti	Mg	Bo	Pr	Ir	Tl	Ca	Re	Zn	Dis-trict of	Nature of samples
Brown sphalerite (Vedrin)	−	+	f	+	+	−	−	−	+	−	+	−	−	−	−	−	−	−	−	−	−	f	−	f	−	−	−	+	−	−	−	tr	+		TF		
Brown sphalerite (Vedrin)	+	+	+	+	+	f	−	−	+	−	f	−	−	−	−	−	−	−	−	−	−	f	−	f	−	−	−	+	−	−	−	−	+		TF		
Brown sphalerite and Galena (Vedrin)	+	+	f	TF	+	f	−	−	−	−	f	−	−	−	−	−	−	−	−	−	−	f	−	f	−	−	−	+	−	−	−	−	+		TF		
Marcasite (Vedrin)	+	TF	f	f	+	f	−	−	−	−	tr	−	−	−	−	−	−	−	−	−	−	f	−	f	−	−	−	+	−	−	−	tr	+		+	Vedrin	Marcasites
Marcasite (Vedrin)	+	TF	f	+	+	f	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	f	−	f	−	−	−	+	−	−	−	ftr	+		+		
Marcasite (Vedrin)	+	TF	f	+	+	f	−	−	−	−	tr	−	−	−	−	−	−	−	−	−	−	f	−	f	−	−	−	+	−	−	−	−	+		+		
Marcasite (Vedrin)	+	TF	f	+	+	f	−	−	−	−	ftr	−	−	−	−	−	−	−	−	−	−	f	−	f	−	−	−	+	−	−	−	tr	+		+		
Galena (Vedrin)	−	+	f	TF	+	−	−	−	+	−	−	−	−	−	−	−	−	−	−	−	−	tr	−	f	−	−	−	+	−	−	−	−	+		+		
Galena (Vedrin)	−	+	f	TF	+	−	−	−	+	−	−	−	−	−	−	−	−	−	−	−	−	tr	−	f	−	−	−	+	−	−	−	tr	+		+		
Microcrystalline and Galena (Vedrin)	−	+	−	TF	+	−	−	−	+	−	−	−	−	−	−	−	−	−	−	−	−	tr	−	f	−	−	−	+	−	−	−	tr	+		+		
Galena (Vedrin)	−	+	f	TF	+	−	−	−	+	−	−	−	−	−	−	−	−	−	−	−	−	tr	−	f	−	−	−	+	−	−	−	tr	+		+		
— — — — —	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—		—		
Galena with big cleavage planes (Bleyberg)*	5+	1+	3+	TF	2+			tr	−	ftr												2+	3+				2+	tftr			ftr	1+		2+	Moresnet	Galena
Saccharoidal Galena (Membach)*	5+	2+	3+	TF	1+			ftr	2+	tr												1+	2+				2+	ftr			tr	4+		5+		

* Professor Buttgenbach samples analysed by Mr. P. Coheur whose notations are given in extenso (1+ to 5+ indicate relative arbitrary amounts).

TF: very high intensity. f: weak intensity. ftr: weak traces. +: present.

F: high intensity. tr: traces. tftr: very weak traces. −: absent.

portions are also less in galena than in sphalerite. No copper minerals were recognized.

Mn, Cd, Ag, Ge have been detected in nearly all sulphides. The presence of Mn in marcasite accounts for the fact that limonites derived from the sulphides are often rich in Mn. Galena from Moresnet was said to contain 100 gr. of Ag per metric ton. The amount of Ag seems to be more important in the sphalerite from Engis than in that from Moresnet. Ge is less at Vedrin than in the other localities.

COMPARISON WITH SPHALERITES FROM OTHER MAGMATIC PROVINCES.

As a whole, the elements included in the sphalerite of the metallogenetic Meuse-Vesdre Province are: Fe, Mn, Cd, Ge, Cu, Ag, and more irregularly, Sn, Ni, Co. The combination of Fe, Mn, Cd, Ge with sphalerite are well known and are in agreement with modern crystallographic theories. The relations of Cu and Ag are less clear. Ag may be combined in argentiferous galena but I have not found copper minerals. The chemical associations of Ag and Cu with sphalerite are not well known as pointed out by Warren and Thompson. The absence of *Ga* differentiates the deposits of Moresnet-Engis-Vedrin from the similar ones of the Mississippi Valley. *As* rarely appears in weak traces whereas it is common in the lead-zinc veins of the eastern Alps (Cretaceous and Pliocene deposits), according to M. Tornquist. *Tl* is found in weak or very weak traces but it is common in England.

I hope that these few data[2] will usefully complete the numerous ones given in Table 4, p. 330 of Warren and Thompson's important study.

THEORETICAL CONCEPTIONS AND SPECIAL ASSOCIATIONS.

The chemical characteristics of hydrothermal solutions depend on the source magma. Each magma has its own type and the hydrothermal solution keeps the elements unsolidified in the course of the preceding crystallizing stage. Consequently, if rare elements or satellites are encountered in a number of samples collected over a large ore-bearing area, and if they are found in comparably equal relative amounts, one may conclude that this fact is not a mere coincidence but due to a common origin and process of formation.

Peculiar results exclude the possibility of mineralizing sources having undergone different conditions of temperature, pressure or concentration, because relative solubility of satellites varies with the conditions of transport and deposition. A collection of rare elements that bear a definite quantitative ratio substantiates the assumption of "consanguinity" for the deposits from which the analyzed specimen were selected.

These theoretical conceptions have brought me to the same conclusions as that derived from Warren and Thompson's research, that is: the governing factor as to the presence of rare elements in sphalerites is the original composition of the parent-magma. The variations resulting from modifications of temperature and pressure are then superimposed.

[2] I have not discussed the presence of Ca, Mg, Si, Al, which are in gangue minerals.

The results of the studies on the sulphides of the Meuse-Vesdre metallogenetic province deal with one only type of mineralization, *i.e.*, the téléthermal deposits. I am thus unable to point out variations of the rare elements percentage connected with changes of temperature at the moment of the deposition. In my opinion, in the study of the variations in the associations of rare elements and sulphides, with modifications of temperature, it is desirable to restrict the investigations only to deposits connected with a same magma.

It is equally impossible to bring new data to the problem of zonal distribution of ores in Belgium. Constant differences could be accounted for by temperature variations at the moment of deposition with respect to variable distances from the mineralizing source. One result only is reached: I determined the criteria of consanguinity and verified constancy in the investigated field.

Having attained this first result, I attempted to investigate further the problem of "impurities" in minerals. I undertook a mineralographic study of Vedrin Mine (8) and came to the conclusion that this mineralization is due to only one phase of deposition characterized by numerous recurrences. The mineralogy is very constant and simple in the course of the long period of crystallization; it consists of Fe, Pb, Zn sulphides and calcite. The three sulphides crystallized from the same solution and sometimes simultaneously. This special occurrence is particularly convenient to determine differences owing to the mineralogical composition of the host-sulphides, and therefore I could distinguish differences in sphalerite, galena and marcasite. The conclusions are summed in Table II.

TABLE II.

	Mn	Sn	Cd	Ge
Sphalerites (4 samples)	+	W	+	+
Marcasites (4 samples)	+	W	−	tr.
Galenas (4 samples)	−	−	+	−

W = weak; + = present; − = absent; tr = traces.

Mn, Sn, Ge are absent in galena but they are present in sphalerite and marcasite. The marcasite does not contain any Cd. These observations restricted to three minerals that belong to one and same phase of mineralization are therefore of a great interest.

The sulphides examined were collected at places far apart (several hundreds of meters). It is quite impossible, therefore, that twelve samples selected at random would all have been crystallized at the same moment. However, it appears that each sulphide has captured some elements to the exclusion of others. It should thus be admitted that the chemistry of the medium remained constant during the evolution of the thermal solution characterized by successive depositions, and that the peculiar phenomena have come about, since similar sulphides contain the same elements.

My investigations show a certain "sympathy" between the different satellites and the sulphides that have captured them.

CONCLUSIONS

My investigations determined the characteristic elements included in the sulphides of the deposits located along the Meuse and Vesdre Valleys, and indicate the selective precipitation of satellites in respect to the kind of host-sulphides.

In the zonal distribution, concentration is admitted to be the controlling factor of mineral deposition.

In the case of the rare elements, phenomena appear that are more connected to the crystallization phase of minerals.

Laws governing these associations are physical ones. But indirectly, one is brought back to physico-chemical laws, because the chemical nature of solutions, some concentration, temperature and pressure ratios favor one crystal lattice or another.

The laws that control the distribution of chemical elements are different if these are only "impurities" in the sulphides and probably also in the minerals, or if they are the essential constituents of deposits occurring around a magma.

The problem is amplified; one cannot make the spectrographic study of sphalerite derived from one magma and compare the distribution of minor elements with the distribution in zones of the mineralization.

I wrote in 1943, in a first study on that subject: "it is of the highest interest to analyze all of the sulphides of an individual deposit, whether it is due to one or several phases, and to determine whether the minor elements systematically depend on the relative age of one phase or also on the crystalline kind or stage of the host-sulphides."

I read, with the greatest pleasure, that part of my suggestions have received confirmation by the practical study of Warren and Thompson. In fact, these investigators distinguished several phases of mineralization. They say (p. 330): "Conversely, we may expect that it will be possible, on the basis of minor elements content, to differentiate between two phases or periods of mineralization in one area" and further: "On the basis of these analyses, the suggestion is that there are three different magmatic sources for these four properties. . . ."

I also hope that similar investigations will be applied to the minerals issued from deep-seated eruptive rocks.

An important field of research is offered to students, and particularly in the range of orthomagmatic deposits. The study must not be restricted to ore minerals. It ought to be enlarged to the gangue minerals which certainly offer great possibilities.

ACKNOWLEDGMENTS.

I am greatly indebted to M. Professor H. Buttgenbach who gave me six analyses made by M. P. Coheur, assistant in Metallurgy at the University of Liege.

I am also grateful to M. P. Coheur who kindly lent me his documents and laboratory, and to M. F. Monfort, graduate in Physics who helped me in the manipulations and interpretations of spectras.

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REVIEWS *

Fortress Islands of the Pacific—Their Geography and Strategic Importance. By WILLIAM H. HOBBS. Pp. xiii + 186; Figs. 107. J. W. Edwards, Ann Arbor, Mich., 1945. Price, $2.50.

At a time when decisions must be forthcoming regarding the part the United States shall play in the governing and development of the many islands of the western Pacific, it is imperative that the geography of these islands be understood. Professor Hobbs here discusses these islands and island groups with a view to their geology and strategic importance. The geography of the various islands, as determined by their geologic history, is of utmost importance in considering their military and political value as well as their economic possibilities. Of the many islands in the area, few are ideal as naval bases and control centers.

Professor Hobbs classifies the islands as: arcuate (newborn and youthful) and strewn, with the non-arcuate including: volcano islands, almost-atolls, atolls, part-raised atolls, and raised atolls. The development of atolls is clearly described and well illustrated. The origin of island arcs is stated, without question, as the result of forces from the Pacific basin causing ridges with adjacent troughs. Major chapter headings follow the classification. Military value of each island type, network of essential Pacific bases, and catastrophic "visitations" to the area are dealt with in separate chapters.

Each of the important islands, groups, or chains is discussed under the proper chapter heading. The descriptions lack uniformity, for, although the geology of each is given, discovery data and development are occasionally lacking as are descriptions of peoples, population data, climate, and economic importance. For example, in the Ryukyu chain only the peoples of Okinawa are discussed and here information relative to important recent emigrations is lacking. No mention is made of the aborigines of the Kuriles, the *Ainu*. It is unfortunate that Professor Hobbs saw fit to exclude strategic Sakhalin island. The physical geography of each island or group is excellently described. This is largely due to Hobb's first-hand observation of much of the area. Numerous pen-and-ink sketches and 83 outline maps aid in portraying the islands.

Professor Hobbs has dealt with a timely subject in a clear and interesting manner. The book is an important contribution.

RALPH E. DIGMAN.

Minerals of Might. By WILLIAM O. HOTCHKISS. Pp. 206. Jaques Cattell Press, Lancaster, Pennsylvania, 1945. Price, $2.50.

Dr. Hotchkiss, well known to our readers as former State Geologist of Wisconsin, former President of Michigan College of Mining and Technology and President Emeritus of Rensselaer Polytechnic Institute, has presented with authoritative background an extremely readable book in concise nontechnical language for the every-day reader. He tells of the role that mineral resources play in modern civilization and particularly the part they play in war. He impresses upon

* Books noted under *Reviews* and *Books Received* may be ordered through the Economic Geology Bookshop, M. M. Leighton, Urbana, Ill., but orders for official reports and single copies of Journals should be sent directly to their publishers.

the reader the enormous drain upon our domestic mineral resources between World War I and 1939. When the figures of domestic production and depletion of reserves that has taken place during World War II are finally released there will be a shocked realization of the rapidity of depletion of reserves of the important war minerals even during the last five years.

The book is written in dialogue style as conversations between the author and a group of executives while sailing through the Great Lakes. Its eight chapters are: What Are Natural Resources?; Development of the Use of Natural Resources in War and in Peacetime; Present Sources of the World's Metals; Sources and Production of Mineral Fuels and other Non-metallics; Reserves of Mineral Resources; The Peace Future of Mineral Resources; and Mineral Resources and World War III. Some thirty tables present data on prewar production and reserves. The author concludes by advocating the building up of adequate stockpiles of war minerals against a future possible emergency.

A. M. B.

Coasts, Waves, and Weather for Navigators. By JOHN Q. STEWART. Pp. 348 quarto; many illustrations. Ginn and Company, New York, 1945. Price, $3.75.

This beautifully printed and profusely illustrated book, with many excellent aerial photos, deals with coast lines, oceanography and meteorology. Although intended primarily to explain to air and marine navigators the physical environment in which navigation must be carried on, it is also an excellent text and reference book on coast lines, oceanography and meteorology, and any geologist or geological student will find much of interest and value in it. A frontispiece displaying an areal view of great glacial grooves in Northern Canada would stir the interest of any glaciologist.

Part I on Coast Lines, Terrain and Routes contains 10 chapters dealing with types of coast lines—highland, lowland, volcanic, coral, bars and deltas, harbors, and rivers. Two other chapters are "Terrain as aviators see it" and "World Transportation and its effects on the distribution of population." Part II is Oceanography for Navigators and has 5 chapters dealing with oceanography, the theory and use of tide and current tables, and waves, wind, ocean currents and ice in the sea. Part III, Meteorology for Navigators, contains 3 chapters on descriptive meteorology and weather around the world. It is concluded with a comprehensive list of books and a good index.

The author, a member of the Princeton University Observatory, obviously had access to recent data from the Coast and Geodetic Survey, the Hydrographic Office of the Navy, and the armed forces. Much of it is war material and war photos.

The book is not only excellent for the purpose for which it was written but will prove a godsend to amateur navigators, and will be enjoyed by geographers and geologists.

A. M. B.

Electronic Equipment and Accessories. By R. C. WALKER. Pp. 392; Figs. 344. Chemical Publishing Company, Brooklyn, N. Y., 1945. Price, $6.00.

This book is primarily an introduction to the study of electronics for practical engineers, students, mechanics and others who are not specialists in electronics. It deals with principles, equipment, procedures, and devices. It is extremely readable and practical.

BOOKS RECEIVED.

RALPH E. DIGMAN.

U. S. Geological Survey. Washington.

Bull. 945–C. **Beryllium and Tungsten Deposits of the Iron Mountain District, Sierra and Socorro Counties, New Mexico.** RICHARD H. JAHNS. Pp. 34; Figs. 2; Pls. 16. 1944. Price, $1.25. *Contains a section on the beryllium minerals written by Jewell J. Glass.*

Bull. 945–D. **Tungsten Deposits in Beaver County, Utah.** S. W. HOBBS. Pp. 30; Pls. 9. 1945. Price, 65 cents.

Bull. 946–A. **Manganese and Iron Deposits of Morro Do Urucum, Mato Grosso, Brazil.** JOHN VAN N. DORR, 2d. Pp. 47; Figs. 6; Pls. 6. 1945. Price, 75 cents.

Water-supply Papers,

919. **Ground-water Resources of the El Paso Area, Texas.** A. N. SAYRE AND PENN LIVINGSTON. Pp. 190; Figs. 11; Pls. 16. 1945.

948. **Water Levels and Artesian Pressure in Observation Wells in the U. S. in 1942. Part 5. Northwestern States.** O. E. MEINZER, L. K. WENZEL AND OTHERS. Pp. 194; Figs. 6. 1944.

949. **Water Levels and Artesian Pressure in Observation Wells in the U. S. in 1942. Part 6. Southwestern States and Territory of Hawaii.** O. E. MEINZER, L. K. WENZEL AND OTHERS. Pp. 344; Figs. 19. 1944.

965. **Surface Water Supply of Hawaii, June 1, 1941 to June 30, 1942.** GLENN L. PARKER AND MAX H. CARSON. Pp. 131. 1945.

976. **Surface Water Supply of the U. S., 1943. Part 6. Missouri River Basin.** GLENN L. PARKER AND OTHERS. Pp. 470; Fig. 1. 1945.

977. **Surface Water Supply of the U. S., 1943. Part 7. Lower Mississippi River Basin.** GLENN L. PARKER AND OTHERS. Pp. 388; Fig. 1. 1945.

980. **Surface Water Supply of the U. S., 1943. Part 10. The Great Basin.** GLENN L. PARKER AND OTHERS. Pp. 185; Fig. 1. 1945.

981. **Surface Water Supply of the U. S., 1943. Part 11. Pacific Slope Basins in California.** GLENN L. PARKER AND OTHERS. Pp. 413; Figs. 2. 1944.

983. **Surface Water Supply of the U. S., 1943. Part 13. Snake River Basin.** GLENN L. PARKER AND OTHERS. Pp. 233; Fig. 1. 1945.

984. **Surface Water Supply of the U. S., 1943. Part 14. Pacific Slope Basins in Oregon and Lower Columbia River Basin.** GLENN L. PARKER AND OTHERS. Pp. 233; Fig. 1. 1945.

987. **Water Levels and Artesian Pressure in Observation Wells in the U. S. in 1943. Part 2. Southeastern States.** O. E. MEINZER, L. K. WENZEL AND OTHERS. Pp. 191; Figs. 12. 1945.

The Survey announces the publication of two maps of the Mosheim anticline area in Green County, Tenn. Plate 1 is a geological map of the area, is 24″ × 18″ with a scale of 1″ to 2000′ and a contour interval of 20′. Geology is by John C. Dunlap and John Rodgers. Plate 2 is a topographic map of the Brown-Tipton zinc area within the anticline. This map is 32″ × 18″, has a

scale of 1" to 100' and a contour interval of 10'. Topography is by Chas. L. Jones. A two-page text by Deane F. Kent and John C. Dunlap accompanies the two maps.

Developments in Eastern interior Basin in 1944. A. H. BELL. Pp. 7; Fig. 1. Illinois Geol. Surv., Press Bull. Ser. No. 51. Urbana, 1945.

Oil and Gas Development in Illinois in 1944. A. H. BELL AND VIRGINIA KLINE. Pp. 44. Illinois Geol. Surv., Press Bull. Ser. No. 52. Urbana, 1945.

Stratigraphy and Oil-producing Zones of the Pre-San Andres Formations of Southeastern New Mexico. ROBERT E. KING. Pp. 34; Fig. 1; Pls. 3. New Mexico Geol. Surv., Bull. No. 23. Socorro, 1945.

A Survey of Weathering Processes and Products. PARRY REICHE. Pp. 87; Figs. 6. Univ. of New Mex. Publication No. 1. Albuquerque, 1945.

Permeability, Porosity, Oil, and Water Content of Natural Gas Reservoirs, Kanawha-Jackson and Campbells Creek Oriskany Fields. A. J. W. HEADLEE AND J. S. JOSEPH. West Va. Geol. Surv., Bull. No. 8. Morgantown, 1945.

Canadian Mines Handbook, 1945. Pp. 320. Northern Miner Press, 122 Richmond St. W., Toronto. Price, $1.00.

Geology of Red Deer and Rosebud Sheets, Alberta. JOHN A. ALLAN AND J. O. G. SANDERSON. Pp. 109; Figs. 37; Pls. 7; Maps 2. Research Council of Alberta, Rept. 13. Edmonton, 1945. Price, 75 cents.

A Bacia de Campos na Geologia Litorânea do Petróleo. ALBERTO R. LAMEGO. Pp. 69; Figs. 28. Ministério da Agricultura, Divisão de Geol. e Mineralogia, Boletim 113. Rio de Janeiro, 1944.

Uma Tartaruga do Cretáceo Superior do Brasil. K. STAESCHE. Pp. 24; Figs. 2; Pls. 5. Ministério da Agricultura, Divisão de Geol. e Mineralogia, Boletim 114. Rio de Janeiro, 1944.

O Desabamento no Morro do Farol em Maceió. A. R. LAMEGO. Pp. 19; Figs. 10. Ministério da Agricultura, Divisão de Geol. e Mineralogia, Numero 24, Notas Prelim. e Estudos. Rio de Janeiro, 1944.

Mapa Geológico do Brasil. 36" × 34"; Scale, 1"=5,000,000. Ministério da Agricultura, Departamento Nacional da Producão Mineral. Rio de Janeiro, 1942.

Cuadernos de Mineralogia y Geologia. Pp. 72; Figs. 11. Universidad Nacional de Tucuman, Instituto de Mineralogia y Geol., Pub. No. 378, Tomo IV—C. 1, No. 13. Tucuman, 1945.

Stratigraphie Generale du Congo Belge et du Ruanda—Urundi. Pp. 10. Congo Belge Service Geologique, Leopoldville, 1944.

Geologic Map of South America, prepared under a Committee of the Geological Society of America in cooperation with the American Geographical Society and the U. S. Geological Survey from maps contributed by South American countries and other sources, by George W. Stose. Published by the Geol. Soc. of America, 1945. Scale 1: 5,000,000. With accompanying explanation of legend (in English, Portuguese, and Spanish) by A. I. Levorsen.

SOCIETY OF ECONOMIC GEOLOGISTS

TWENTY-SIXTH ANNUAL MEETING

POST-WAR MEETING OF THE SOCIETY OF ECONOMIC GEOLOGISTS

WITH THE

GEOLOGICAL SOCIETY OF AMERICA

MINERALOGICAL SOCIETY OF AMERICA

PALEONTOLOGICAL SOCIETY

SOCIETY OF VERTEBRATE PALEONTOLOGY

AS GUESTS OF THE

PITTSBURGH GEOLOGICAL SOCIETY

PITTSBURGH, PA., DECEMBER 27–29, 1945

GENERAL INFORMATION

NOTE: All meetings and sessions, except as expressly indicated, will be held on the Seventeenth Floor of the HOTEL WILLIAM PENN, Pittsburgh, Pa.

Morning technical sessions present papers of general interest to all geologists. Afternoon technical sessions are designed rather for specialized groups. Attention is directed to papers dealing with structural and areal geology, mineralogy and petrology, geophysics, geomorphology, stratigraphy, paleontology, and other subdivisions of the earth sciences which are presented in other rooms of the Seventeenth Floor and are announced in detail in the programs of the Geological Society of America, the Mineralogical Society of America, and the other affiliated societies meeting at the same time.

Mail and messages may be addressed in care of the Registration Desk, Society of Economic Geologists.

Conference rooms and space for exhibits will be provided if applied for in advance through the Secretary of the Society.

SPECIAL FUNCTIONS

Registration

SILVER ROOM

9:00 A.M., THURSDAY, DECEMBER 27, AND THEREAFTER

Members of the Society of Economic Geologists are requested to register as such, in addition to any other concurrent registration.

Council Meetings of the Society of Economic Geologists

PARLOR F

12:00–2:00 P.M., THURSDAY, DECEMBER 27 (WITH LUNCHEON)

PARLOR F

2:00–6:00 P. M., SATURDAY, DECEMBER 29

PARLOR F

8:00–10:00 P.M., SATURDAY, DECEMBER 29 (IF NECESSARY)

Luncheon and Annual Business Meeting of the Society of Economic Geologists

PITTSBURGH ROOM

12:00 NOON, FRIDAY, DECEMBER 28

Reservations, whether made by mail or not, should be secured at Registration Desk *not later than 2 P.M.*, Thursday, December 27. Reports by President O. E. Meinzer, Treasurer J. T. Singewald, Jr., Secretary Chas. H. Behre, Jr., and various committee chairmen; introduction of new members; discussion of proposed Congress of Geological Organizations; plans for future financing of the Annotated Bibliography; and consideration of revision of the by-laws.

Smoker

BALL ROOM

8:00 P.M., THURSDAY, DECEMBER 27

Members and their guests, including ladies are invited by the Geological Society of America to attend. The addresses of the presidents of affiliated societies will be presented:

President Kenneth K. Landes, Mineralogical Society of America: Geological Mineralogy.

President Charles L. Camp, Society of Vertebrate Paleontology: Trends and Developments in Paleontology (By title).

President Chester Stock, Paleontological Society: Progress in Paleontological Research on the Pacific Coast,—1917–1944.

President Oscar E. Meinzer, Society of Economic Geologists: Hydrology in Relation to Economic Geology.

The closing address will be followed by an informal Smoker.

Annual Dinner

BALL ROOM

7:00 P.M., FRIDAY, DECEMBER 28

Members of the affiliated geological societies and their guests, including ladies, are cordially invited. Dress optional. Tickets should be purchased before 2:00 P.M., Thursday, December 27, at the Registration Desk; price, $3.50.

Business and Technical Sessions

BALL ROOM

9:00–12:00 A.M., THURSDAY, DECEMBER 27

Business Meeting of the Geological Society of America, which members of the Society of Economic Geologists are especially urged to attend.

CARDINAL ROOM

2:00–5:30 P.M., THURSDAY, DECEMBER 27

Symposium on lead-zinc ores of the eastern states.
Symposium on alteration associated with ore deposition.
Special papers on ore deposits, ground water, engineering geology.

BALL ROOM

9:00–12:00 A.M., FRIDAY, DECEMBER 28

Geology in war and peace (All-Society Meeting).

CARDINAL ROOM

2:00–5:30 P.M., FRIDAY, DECEMBER 28

Symposium on ground-water recharge.
Symposium on composition and geology of coal.

SILVER ROOM

2:00–5:30 P.M., FRIDAY, DECEMBER 28

Economic geology and mineralogy of certain useful minerals; special papers on mineralogy and occurrence of certain ores.

FORUM ROOM

2:00–5:30 P.M., FRIDAY, DECEMBER 28

Mineralogy in relation to petrology and economic geology; papers on pegmatites and pegmatite minerals.

BALL ROOM

9:00–12:00 A.M., SATURDAY, DECEMBER 29

Recent advances in research; applications of geology to war and peace. (All-Society Meeting.)

DETAILED SCHEDULE OF TECHNICAL SESSIONS

BALL ROOM

THURSDAY MORNING, 9:00–12:00, DECEMBER 27

N. L. Bowen, Acting President, G.S.A., Chairman

Annual Meeting of the Geological Society of America

9:00 Call to order.
Address of welcome: K. C. Heald, speaking for the Pittsburgh Geological Society.
Brief meeting to transact routine business of the Geological Society of America. *All members are especially urged to attend.*

9:30 Agenda designed to cover matters related to the basic policies of the Geological Society of America and of interest to geologists in general:

Report on the National Research Council; the situation as to government support of research; the problem of publicity in geology; the question of coordination of the work of the geological societies; and a discussion of several other matters fundamentally affecting the general policies of the Society.

12:00 Adjournment.

THURSDAY AFTERNOON, 2:00–5:20, DECEMBER 27

URBAN ROOM

Oscar E. Meinzer, President, S.E.G., Chairman

Ore Deposits and Special Papers on Economic Geology

Symposium on Eastern Lead-Zinc Ores and Related Deposits:

2:00 Oder, C. R. L., and Miller, H. W. General stratigraphy of the East Tennessee zinc deposits.

2:20 Dunlap, J. C. Structural control in the eastern belt of the Sweetwater barite district, East Tennessee.

2:40 Brokaw, A. L., and Jones, C. L. Structural control of ore bodies in the Jefferson City, Tennessee, area.

3:00 Willman, H. B. Structure of the zinc-lead deposits of northwestern Illinois.

3:20 Heyl, A. V., Jr., and Agnew, A. F. Structural relations of the Upper Mississippi Valley lead-zinc district.

General Papers Related to Applied Geology:

3:40 Plummer, F. B. Reduction of sulphates in oil-field salt water.

4:00 Laurence, R. A. Foundation exploration and geologic studies at Cherokee and Douglas dams, Tennessee.

Symposium on Rock Alteration as Related to Ore Deposition:

4:20 Lovering, T. S., Stoll, W. M., Wadsworth, A. H., Wagner, H. C., Stringham, B. F., Hilpert, L. S., Smith, J. F., and Terrones, A. Alteration and structure in the East Tintic district, Utah.

4:40 Schwartz, G. M. Hydrothermal alteration in the San Manuel copper deposit, Arizona.

5:00 Peterson, N. P., Gilbert, C. M., and Quick, G. L. Hydrothermal alteration in the Castle Dome copper deposit.

Johnston, W. D., Jr., and Butler, R. D. Quartz crystal in Brazil. (By title.)

Heck, E. T. Tin and tungsten deposits of French Morocco. (By title.)

Kelley, V. C. Tertiary iron ore in Triassic collapse breccia. (By title.)

Myers, W. M. Post-Paleozoic mineralization in Pennsylvania. (By title.)

THURSDAY AFTERNOON, 2:00–5:30, DECEMBER 27

Other Sessions, Chiefly Organized by Affiliated Societies

2:00 Ball Room: Papers dealing chiefly with structural geology and geophysics.

2:00 Cardinal Room: Papers dealing chiefly with structural crystallography and with diamonds.

2:00 Forum Room: Papers dealing chiefly with general mineralogy and mineral genesis.

2:00 Adonis Room: Papers dealing chiefly with paleontology.

FRIDAY MORNING, 9:00–12:00, DECEMBER 28

BALL ROOM

N. L. Bowen, Acting President, G.S.A., Chairman

Geology in War and Peace

9:00 Leith, C. K. Service of the War Production Board.
9:30 Bateman, A. M. Service of the Foreign Economic Administration.
10:10 Heroy, W. B. Service of the Petroleum Administration for War.
10:50 Dryden, Lincoln. The Military Geology Unit, U. S. Geological Survey—purpose, aims, results.
10:56 Fryxell, F. M. Terrain appreciation: military appraisal of terrain.
11:04 Denny, C. S. Construction problems: airfields, roads and general construction.
11:12 Roberts, Ralph. Influence of rock and soil composition on performance of metallic mine detectors.
11:20 Sayre, A. N. Military water supply.
11:28 Aberdeen, Esther. Coral reef sediment at Morotai, N. E. I.
11:36 Edmunds, Clara S. Beach intelligence—Service of the Beach Erosion Board.

FRIDAY AFTERNOON, 2:00–5:20, DECEMBER 28

URBAN ROOM

W. O. Hotchkiss, President-Elect, S.E.G., Chairman

Economic Geology and Mineralogy

2:00 Guild, P. W., and Flint, D. E. Chromite deposits of Camagüey Province, Cuba.
2:25 Thayer, T. P. Preliminary chemical correlation of chromite with the containing rocks.
2:50 Vitaliano, C. J. Magnesium mineralization in the Currant Creek district, Nevada.
3:05 Leatham, Earl. Occurrence and distribution of iron minerals in Pennsylvania fire clays.
3:25 Hendricks, S. B., Goldich, S. S., and Nelson, R. A. Portable differential thermal analysis unit for bauxite exploration.
3:42 Page, L. R. Contact-metamorphic deposits of cassiterite in California.
4:02 Nuffield, E. W. Studies of mineral sulpho-salts: XI—wittichenite (klaprothite).
4:17 Fleischer, Michael, Neuschel, S. K., and Axelrod, J. M. Occurrence of tungsten and vanadium in manganese oxide ores and minerals.
4:37 Yagoda, Herman. Luminescent phenomena as aids in the localization of minerals in polished sections.
4:57 Stadnichenko, Taisia. Modern aspects of geochemistry and their application to economic geology.

FRIDAY AFTERNOON, 2:00–5:40, DECEMBER 28

CARDINAL ROOM

Oscar E. Meinzer, President, S.E.G., Chairman

Coal and Ground Water

Symposium on Ground Water Recharge:

2:00 Meinzer, O. E. General principles of artificial ground-water recharge.

2:20 Unklesbay, A. G., and Cooper, H. H., Jr. Artificial recharge of artesian limestone at Orlando, Florida.

2:40 Barksdale, H. C., and De Buchananne, G. D. Artificial recharge of productive ground-water aquifers in New Jersey.

3:00 Brashears, M. L., Jr. Artificial recharge of ground-water on Long Island, N. Y.

3:20 Guyton, W. F. Artificial recharge of glacial sand and gravel with cold filtered river water at Louisville, Ky.

Symposium on Composition of Coal:

3:40 Parks, B. C., and Cady, G. H. Investigation in petrographic methods of coal analysis.

4:00 Sears, P. B. An introductory statement regarding pollen analysis.

4:20 Wilson, L. R. Application of paleoecological method to an early Tertiary coal seam.

4:40 Schopf, J. M., and Cross, A. T. Plant microfossil investigations in western coals—a progress report.

5:00 Kosanke, R. M. Plant microfossils from Illinois coals.

5:20 Schopf, J. M., and Smith, H. L. Gross petrology of coal in relation to exploration of coal reserves by diamond drilling.

FRIDAY AFTERNOON, 2:00–5:35, DECEMBER 28

FORUM ROOM

K. K. Landes, President, M.S.A., Chairman

Mineralogy, Petrology, and Economic Geology

2:00 Swineford, A., and Frye, J. C. Petrographic comparison of Pliocene and Pleistocene volcanic ash from western Kansas.

2:15 Moyd, L. Petrology of the nepheline and corundum-bearing rocks of southeastern Ontario.

2:35 Fairbairn, H. W., and Sheppard, C. S. Maximum error in some mineralogic computations.

2:55 Chayes, Felix. Linear analysis of a medium-grained granite.

3:15 Maynard, J. E., and Ploger, L. W. An altered saxonite dike, Syracuse, N. Y.

3:30 Lowe, K. E. Construction and study of flow structure models from field data.

3:43 Griffiths, W. R., Heinrich, E. W., Jahns, R. H., Olson, J. C., and Parker, J. M., III. Occurrence of mica-bearing pegmatites in the Southeastern States.

4:03 Page, L. R. Structural and mineralogical characteristics of South Dakota pegmatites.

4:23 Cameron, E. N., Jahns, R. H., McNair, A. H., and Page, L. R. Internal structure of granitic pegmatites.

4:38 Heinrich, E. W. Composite pegmatites of the Franklin-Sylva mica district, North Carolina.

4:53 Hanley, J. B. Beryllium and tantalum pegmatites of Colorado.

5:13 Fisher, D. J. Striking case of pegmatitic albitization.

5:26 Bates, T. F. Investigation of the micaceous minerals in slate.
Foster, W. R. Mineral shape factors for use in quantitative microscopic analysis. (By title.)
Hanley, J. B. Lithia pegmatites of the Brown Derby mine, Gunnison County, Colo. (By title.)
Heinrich, E. W. Bismuth minerals in Colorado and New Mexico pegmatites. (By title.)
Lovering, T. S. Direction of flow of jasperoidizing solution. (By title.)
Lowe, K. E. A graphic solution for certain lineation problems. (By title.)

FRIDAY AFTERNOON, 2:00–5:30, DECEMBER 28

Other Sessions, Chiefly Organized by Affiliated Societies

2:00 Silver Room: Papers dealing chiefly with glacial geology and physiography.
2:00 Adonis Room: Papers dealing chiefly with stratigraphy

SATURDAY MORNING, 9:00–12:00, DECEMBER 29

BALL ROOM

N. L. Bowen, Acting President, G.S.A., Chairman

Geology in War and Peace

9:00 Berkey, C. P. Major responsibilities of an engineering geologist.
9:20 Belcher, D. J. Engineering applications of aerial reconnaissance.
9:45 Leighton, M. M. Illinois Geological Survey's activities in war and peace.
10:15 Ewing, Maurice, and Woollard, G. P. Recent geophysical investigations in the Atlantic Ocean Basin.
10:45 Goodman, Clark, and Whitehead, W. L. Geological implications of atomic energy.
11:30 Two important geophysical papers of general interest by C. L. Pekeris and J. R. Balsley, Jr., respectively, will be presented if declassified in time by military authority.

SATURDAY MORNING, 9:00–12:00, DECEMBER 29

Other Sessions, Chiefly Organized by Affiliated Societies

9:00 Forum Room: Papers dealing chiefly with stratigraphy.
9:00 Adonis Room: Papers dealing chiefly with paleontology.

Adjournment of Technical Sessions

N. B.—Members of the Council of the Society of Economic Geologists are reminded of the resumption of the Council Meeting at 2:00 P.M., Saturday, December 29, in Parlor F.

ABSTRACTS
OF
PAPERS PRESENTED AT THE
TWENTY-SIXTH ANNUAL MEETING

In Conjunction with
Geological Society of America
Mineralogical Society of America
Paleontological Society
Society of Vertebrate Paleontology
As Guests of the
Pittsburgh Geological Society
Pittsburgh, Pa., December 27–29, 1945
Arranged Alphabetically
by
Authors

CORAL-REEF SEDIMENT AT MOROTAI, N. E. I.[1]

E. ABERDEEN, FOR THE STAFF OF THE MILITARY GEOLOGY UNIT.

Photo-reconnaissance of Morotai, N. E. I., led to selection of the terraced, reef-bordered, southwestern peninsula of the island for airfield construction. The western shore of the peninsula, protected from southeast monsoonal winds and with approaches over an apparently shelving, sand-covered coral reef, was chosen for combat landings. On D-day, the reef on this side was found to be unsuitable because the apparent sand-cover was actually thick, unconsolidated sediment or sludge of very low bearing ratio. Hasty ground observations and study of the literature suggest that the sludge is formed under the following conditions: calcium bicarbonate in streams draining the limestone-terrace area is precipitated, by bacterial action, as a fine calcareous flocculate in the coastal mangrove swamps north of the landing area. Slow-moving, southerly longshore currents drift this precipitate from the mangrove swamps onto the reef surface. Almost complete protection from wave action permits the accumulation of a thick sludge cover.

In later over-reef landing operations, recognition of similar unfavorable conditions was made possible by the knowledge gained at Morotai.

ARTIFICIAL RECHARGE OF PRODUCTIVE GROUND-WATER AQUIFERS IN NEW JERSEY.[2]

HENRY C. BARKSDALE AND GEORGE D. DEBUCHANANNE.

Artificial recharge by water spreading is practiced in several places in New Jersey. Rates of recharge ranging from 4,000 to 90,000 gallons per acre per day have been measured at the Perth Amboy Water Works, where artificial recharge of the Old Bridge sand, of upper Cretaceous age, has been practiced for more than 30 years. At the Duhernal development, which also draws from the Old Bridge sand, more than four million gallons daily is now derived from artificial recharge.

[1] Published by permission of the Director, United States Geological Survey.

[2] Published with the permission of the Director, Geological Survey, United States Department of Interior and the Chief Engineer, New Jersey State Water Policy Commission.

This rate will probably increase with further lowering of the water table near the lake. For many years the Princeton Water Company has pumped water from a stream for recharging the Stockton sandstone, of Triassic age. The City of East Orange spreads the water from several small streams over parts of the intake area of the Quaternary beds supplying its wells. The estimated total recharge is about a million gallons daily. Closely related to artificial recharge are those instances wherein well sites are chosen to take advantage of potential recharge from existing bodies of surface water. At the Borough of Manville no water spreading operations are conducted, but about 80 per cent of the water from its wells is derived by recharge from the Raritan River.

ARTIFICIAL RECHARGE OF GROUND-WATER ON LONG ISLAND, NEW YORK.[1]

M. L. BRASHEARS, JR.

In 1933, the water table in a large area in western Long Island was below sea level and potability of ground water was threatened by inflow of sea water. To prevent further overdevelopment, the New York State Water Power and Control Commission has required that water pumped from new wells for cooling and similar purposes be returned to the ground. During the summer of 1944, over 200 recharge wells and several recharge pits were returning water at the combined rate of about 60,000,000 gallons a day. Also in operation were several large recharge pits which return storm sewer runoff in Nassau County. The water is returned to glacial beds from which most of it is pumped but in places it percolates into the underlying Cretaceous formations. Well drillers have developed recharge wells capable of returning as much as 1,000 gallons a minute, many of them having been in operation for over five years without failing. Recharge pits dug in coarse glacial gravels are capable of returning about 1,000,000 gallons a day per acre of exposed surface. The legal requirement that water pumped for cooling be returned to the aquifer has caused a gradual decrease in net withdrawal of ground water but has increased actual use. Hence a rise in water levels has occurred in the critically overdeveloped area. Water levels reached lowest stage at end of 1941 and have recovered slowly since then. However, water levels are still far below sea level in many places and sea water continues to move inland in areas of heavy pumping.

STRUCTURAL CONTROL OF ORE BODIES IN THE JEFFERSON CITY, TENNESSEE AREA.[2]

ARNOLD L. BROKAW AND CHARLES L. JONES.

The zinc deposits of the Jefferson City area are confined to the lower half of the Kingsport formation of the Knox group of rocks. They are on the southeast flank of a northeast-trending anticline which is partially overridden from the southeast by the Bays Mt. thrust sheet. The beds show low dips. The area is transected by a series of high angle strike-slip faults having relatively small displacement and striking essentially parallel to the dominant northeast structure. Minor cross folds running transversely to the regional structure are numerous. Three sets of fractures trending N. 45–50° W., N. 30–40° E., and N. 60–70° E. are well developed.

The ore bodies are irregular but generally have a distinct elongation. The vertical extent may be limited to a single bed or may include several beds, depending upon local structural conditions. All ore bodies are confined to zones of premineral deformation. The linear trends of the ore bodies show a remarkable parallelism to the axes of the cross folds. Ore occurs on any part of the flexures

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but maximum concentration is on the anticlinal crests and synclinal troughs; the ore attains greatest thickness on the anticlines. Fractures associated with the folding exhibit local ore control. Faults are poor sites for ore, but fracturing and drag folding accompanying faulting produce conditions favorable to ore deposition.

INTERNAL STRUCTURE OF GRANITIC PEGMATITES.[1]

E. N. CAMERON, R. H. JAHNS, A. H. MCNAIR, AND L. R. PAGE.

It has long been recognized that many pegmatite bodies are divisible into lithologic and structural units of contrasting composition or texture, but no classification of these units applicable to large groups of pegmatites has appeared. Recent investigations of pegmatite mineral deposits by the Federal Survey during a period of unusually widespread mining operations gave an exceptional opportunity for detailed structural analysis of pegmatite bodies. Some forty geologists were engaged in this work, chiefly in South Dakota, Colorado, Wyoming, Idaho, New Mexico, the Southeastern States, and New England. Comparisons of findings indicate that certain types of lithologic and structural units are common in pegmatites studied in all districts. The various types will be described and illustrated, and a general classification of pegmatite units will be discussed.

LINEAR ANALYSIS OF A MEDIUM GRAINED GRANITE.

FELIX CHAYES.

The design and results of an experimental evaluation of the precision of linear analysis are described. It is shown that no systematic error is introduced by duplicate or multiple measurements of the same grain, providing the traverses are evenly spaced throughout. The precision error, whether of a single linear analysis or of a mean based on a group of such analyses, varies directly with the traversing interval. The mean of a large number of linear analyses will not differ from a true Rosiwal analysis of the same group of slides.

Numerical statements of these conclusions are given for the Woodstock, Maryland, granite as analyzed by the writer on the Hurlbut and Wentworth-Hunt micrometers. The precision error of a single analysis is small in comparison to differences between thin sections; in this case it may be neglected. It is shown by comparison of Hurlbut- and Wentworth-stage results that the precision of the two instruments is of the same order.

CONSTRUCTION PROBLEMS: AIRFIELDS, ROADS, AND GENERAL CONSTRUCTION.[2]

C. S. DENNY, FOR THE STAFF OF THE MILITARY GEOLOGY UNIT.

In World War II, vastly increased use of air power and motorized ground equipment necessitated a comparable increase in planning for airfields and roads. For this purpose, military geologic intelligence studies coordinated data on, and interpretations of, ground, terrain, and drainage conditions. The types of information that could be supplied were: Selection of possibly suitable areas (or even of actual sites) for airfield and road construction; evaluation of soil and rock conditions in possible construction areas or sites, for estimating ease of construction; evaluation of special topographic and drainage problems; determination of sources of construction materials and evaluation of their general suitability. The success with which these various types of information could be supplied depended on the basic information available. Where geologic maps, soils maps, and aerial photographs were on hand, remarkably accurate selections of sites and determinations of ground conditions were possible.

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The study of construction problems in military operations has emphasized the need for more basic data on the engineering properties of soils and rocks, first to establish general ground conditions, and second to determine the particular uses for which different soils and rocks are most suitable.

THE MILITARY GEOLOGY UNIT.[1]

LINCOLN DRYDEN, FOR THE STAFF OF THE MILITARY GEOLOGY UNIT.

In 1942, acting under the Corps of Engineers, U. S. Army, the Military Geology Unit, U. S. Geological Survey, was organized to furnish reports to be used at the strategic level of military planning. Intended for the use of Engineer and other officers, reports on terrain, water supply, and construction problems were phrased in non-technical language. Particular emphasis was placed on terrain diagrams, maps, and other graphic means of presentation. Favorable reception of early reports, at the planning level and in combat areas, led to an expansion of the staff from an original 10, to 125 members. To date, the Unit has completed more than 150 folio reports (of from 25 to 200 pages each) on all major combat areas. In addition, starting in 1944, the Unit has sent members of the staff overseas to help with tactical planning and construction and reconstruction problems. Approximately 75 members have served overseas.

The experience of the Unit has demonstrated: (1) That practical applications of geology and soils science can play an important role in military planning and operations. This fact is fully appreciated by the Corps of Engineers, who are requesting continued, peace-time work by the Unit. (2) That there is great need for collecting additional basic geologic and soils data, not only in almost unknown Pacific areas, but in our own country as well.

STRUCTURAL CONTROL IN THE EASTERN BELT OF THE SWEETWATER BARITE DISTRICT, EAST TENNESSEE.[2]

JOHN C. DUNLAP.

This district, near the center of the Appalachian Valley and Ridge Province and forty miles southwest of Knoxville, consists of three parallel belts of Cambrian and Ordovician sediments separated by major thrust faults, with a barren belt between the eastern and the two western belts. Currently 3,400 tons of barite are produced monthly, all from residual deposits.

The deposits are restricted to the Beekmantown division of the Knox dolomite group, and occur principally in the limestone member of the lower Kingsport formation; but where structural conditions are favorable, deposits are also found in the Mascot dolomite and limestone above and in the Chepultepec dolomite below. The beds strike N. 50° E., and dip 10 to 20° southeast. Two types of minor structures, causing narrow fractured and brecciated zones, cut across the regional structure and are believed to control the mineralization. These are (1) "kinks" or sharp flexures caused by abrupt change in strike and (2) very gentle anticlines. The axes of the minor structures are inadequately known because of few outcrops, but probably strike about N. 70° W. with variations from N. 20° W. to due west.

Pyrite, fluorite, and barite, listed in order of deposition and increasing abundance, form banded veins in coarse breccia. Traces of sphalerite and galena are found in some of the deposits. Silicification, evidenced by the abnormally large amount of chert in the vicinity of the deposits, is a noteworthy feature.

The barite and associated minerals are believed to have originated from hydrothermal solutions rising through the fractured zones and spreading laterally along favorable beds.

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BEACH INTELLIGENCE–SERVICE OF THE BEACH EROSION BOARD.

CLARA S. EDMUNDS, FOR THE STAFF OF THE BEACH EROSION BOARD.

The Beach Erosion Board operates as a unit of the Chief of Engineers, War Department. Its part in beach intelligence began in June 1942 with a report of channel coast beaches of France from Cherbourg to Dunkirk, and by the end of that year a program of a continuing succession of Strategic Engineering Studies on foreign beaches was well underway. Later the Board's reports were written directly for a volume published by a joint army and navy intelligence group. Two main types of reports have evolved from the early beginnings. One of these is a brief graphic form used for strategic planning; the other is a longer, completely detailed operational report. The final development is the type of operational report written by intelligence teams overseas; such teams as those made up of members of the Military Geology Unit of the Geological Survey with one or two members of each team cooperating with the Beach Erosion Board.

An example is given of the approach used in writing a short strategic planning report, and an evaluation is made of the methods used in correlating available data into a complete physical picture of a particular beach area.

RECENT GEOPHYSICAL INVESTIGATIONS IN THE ATLANTIC OCEAN BASIN.

MAURICE EWING AND G. P. WOOLLARD.

The onset of the war interrupted our scientific work and held up the publication of results on the geophysical investigations in the ocean sponsored by the Penrose Fund of the Geological Society of America.

During the war period nearly all of the established methods of submarine geology were found to have military applications and as a result of the impetus given to such work by Government research and development contracts, new techniques were developed. Thus the field work of the war period has both added considerably to the store of knowledge gained through established methods and has demonstrated the potential usefulness to submarine geology of entirely new instrumentation.

The cooperation of geophysicists, submarine geologists and oceanographers with the Navy's research program has been particularly close and effective. It has led to improvements in the methods of both deep sea and shallow water seismic surveys, to advances in the techniques of underwater photography and to the development of other rapid systems for collecting information about the sediments. Some examples of the results achieved by investigators working at the Woods Hole Oceanographic Institution are presented.

As an example of an entirely new tool for the exploration of ocean basins a method of acoustically scanning the floor of the deep ocean is explained. This method is particularly promising for the location of active submarine volcanoes and isolated submerged mounts which cannot easily be found by conventional sounding techniques.

MAXIMUM ERROR IN SOME MINERALOGIC COMPUTATIONS.

H. W. FAIRBAIRN AND C. W. SHEPPARD.

The notable lack of quantitative information regarding errors in many mineralogic computations has prompted the writers to construct a series of diagrams from which such information can be readily obtained. These include various determinative methods for density, refractive index, birefringence, and optic angle. Assuming a skilled operator and good working material, maximum values of the error in single observations are assigned to each procedure, so that the diagrams

depict "worst" values of error rather than "probable" error as determined by standard methods from a series of observations. Comparison of the various procedures is based on this maximum expected error.

OCCURRENCE OF TUNGSTEN AND VANADIUM IN MANGANESE OXIDE ORES AND MINERALS.[1]

MICHAEL FLEISCHER, K. NEUSCHEL AND J. M. AXELROD.

The occurrence of tungsten in manganese oxide ores was first noted by Penrose in 1890 and since has been discussed by several authors. Vanadium has been reported in four analyses of manganese oxides. New analyses in the Chemical Laboratory of the Federal Geological Survey have shown that these elements occur commonly in manganese oxide ores, especially in those from the southwestern United States. Over fifty new occurrences have been noted and many more will doubtless be found by systematic chemical testing.

In some deposits, the tungsten and vanadium content of the ore varies directly with the manganese content, indicating that the tungsten and vanadium are in the manganese oxide mineral. This is not true of a few deposits, including that at Golconda, Nevada. X-ray study and chemical analysis show that tungsten and vanadium occur most frequently in manganese oxides that contain barium. Over three-fourth of the tungsten-bearing samples studied are the barium manganate psilomelane. Over two-thirds of the vanadium-bearing samples studied are either psilomelane or hollandite.

No generalizations can yet be made as to the origin of the tungsten-bearing and vanadium-bearing manganese oxide ores. Many are of hydrothermal origin, but some appear to be secondary.

TERRAIN APPRECIATION: MILITARY APPRAISAL OF TERRAIN.[2]

F. M. FRYXELL, FOR THE STAFF OF THE MILITARY GEOLOGY UNIT.

Terrain appreciation implies description and appraisal of terrain in terms of its effects on movement of military forces and, incidentally, on cover, concealment, and observation. The appraisal is essentially an interpretation of data on physiography, ground conditions (rock and soil), and also land use, communications, and climate. Although the problem is fundamentally geologic, the need for details on soils and vegetation requires that specialists in these fields collaborate with geologists. The studies originally emphasized movement on existing routes, treating cross-country movement only in general terms. As the demand arose for more detail on problems of movement off roads, the treatment was supplemented by "trafficability" maps, showing the probable effects of soil, slope, vegetation, and weather upon movement of military traffic, particularly armor. The accuracy of the interpretations depended upon the available data, and on the time permitted for their study. Where the data were good, results were remarkably satisfactory. Where the information was scanty or lacking, the gap was filled by analogy with physiographically similar areas, and interpretations were correspondingly generalized. Often, material had to be sacrified to save time.

Experience in this work has clearly justified the geologic approach to the problem, and has strongly emphasized the value of collecting all possible data on geology, topography, and soils. The trafficability studies, moreover, revealed a need for data on military vehicular performance as related to definite terrain and soil conditions, and on the behavior of various types of soil under traffic in different weather conditions.

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OCCURRENCE OF MICA-BEARING PEGMATITES IN THE SOUTHEASTERN STATES.[1]

W. R. GRIFFITTS, E. WM. HEINRICH, R. H. JAHNS, J. C. OLSON, AND J. M. PARKER, III.

Mica-bearing pegmatite has been mined extensively in the southeastern United States, particularly in eleven well defined districts. The Spruce Pine and Franklin-Sylva districts in the Blue Ridge province of North Carolina, and the Alabama and eastern Virginia Piedmont areas are gealogically representative of the entire group. Nearly all the deposits occur in mica and hornblende gneisses and schists, and appear to be genetically related to near-by leucocratic intrusive rocks that range in composition from quartz monzonite to quartz diorite. About four-fifths of the pegmatites in the Alabama and Spruce Pine districts are sills or concordant tongues and lenses; most of the others in the Spruce Pine district are dikes in coarse-grained granodiorite and quartz diorite. In contrast, most of the Franklin-Sylva and Virginia pegmatites are steeply dipping dikes, discordant lenses, and more complex bodies.

Plagioclase, quartz, microcline, and muscovite are the dominant pegmatite constituents. Biotite, garnet, and apatite are common accessories; beryl, tourmaline, and sulfide minerals are sparse but widespread in some districts; and lithium, tantalum-columbium, tin, and uranium minerals are rare except in a few Virginia deposits. Nearly all the pegmatite bodies appear to have formed from the walls inward, perhaps by crystallization from liquid. Definite evidence for or against their development by large-scale, complete or nearly complete replacement of pre-existing pegmatite is almost lacking. Although some of the minerals and mineral aggregates plainly were formed by replacement, only a small proportion of material can be assigned such an origin with assurance.

CHROMITE DEPOSITS OF CAMAGUEY PROVINCE, CUBA.[2]

PHILIP W. GUILD AND DELOS E. FLINT.

The chromite-bearing ultramafic complex near Camaguey, Cuba, mapped as a part of the program of mineral investigations of the Federal Geological Survey, consists chiefly of serpentinized peridotite (harzburgite) and dunite, with minor amounts of the feldspathic rocks gabbro, troctolite, and anorthosite. This complex and the overlying Cretaceous tuffs and limestones were severely deformed in an orogeny which culminated in extensive thrust faulting, probably in late middle Eocene time. The Sedimentary rocks now occur in two synclinal arcs extending across the district parallel to the trace of the thrust. The feldspathic rocks of the complex flank the tuffs along the limbs of the syncline, indicating that they were concentrated in the upper part of the complex.

The chromite occurs as tabular or lenticular bodies of massive, coarse-grained, or occasionally fine-grained disseminated ore. Virtually all the known deposits are near the base of the feldspathic zone, but with an irregular lateral distribution which distinguishes them from the layered chromitites of the Bushveld-Stillwater type. Two possible modes of origin are discussed: (1) segregation of the deposits near the feldspar-peridotite boundary after emplacement of the magma through some process of gravity separation and magmatic flow; (2) differentiation of chromite at great depth before intrusion and transportation of the ore bodies as solid masses to their present position. The grouping into clusters, as though near feeders, and the massive texture and sharp contacts of many of the deposits suggest that the latter hypothesis is more probable.

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ARTIFICIAL RECHARGE OF GLACIAL SAND AND GRAVEL WITH COLD FILTERED RIVER WATER AT LOUISVILLE, KY.[1]

W. F. GUYTON.

Records obtained by the Geological Survey, United States Department of the Interior, and the Geological Division, Kentucky Department of Mines and Minerals, indicate that industries at Louisville pumped about 62 million gallons a day of water from wells in 1943. This was over 20 million gallons a day more than the natural recharge to the glacial outwash sand and gravel from which the wells draw the water. The ground water is especially in demand because of its uniform low temperature throughout the year. In order to stop the resulting serious decline of water levels and decrease in yields of wells, the pumpage is now gradually being reduced. Also, the recharge has been increased about 2 million gallons a day by introducing water into the aquifer through wells.

During the spring of 1944 the Seagram and National distillers helped solve a local shortage of ground water by recharging the underground reservoir with 1.7 million gallons a day of cold water from the municipal river-water supply. While this water was being added to the aquifer through several supply wells the plants were operated with additional city water, and the rest of the supply wells were kept idle. In this way, the large cone of depression in the water table that had been created by heavy pumping from the wells was practically filled with cold water from a combination of natural and artificial recharge. As a result, during the summer when the city water became too warm to be used in the plants, an increased and ample supply of cold water was available from the wells. It has been suggested that other industries at Louisville might adopt similar procedures for insuring adequate supplies of cold water during the summers.

LITHIA PEGMATITES OF THE BROWN DERBY MINE, GUNNISON COUNTY, COLORADO.[2]

JOHN B. HANLEY.

Three parallel, elongate lithia pegmatites crop out at the Brown Derby mine in sec. 3, T. 49 N., R. 3 E., Gunnison County, about 17 miles by airline due east of the town of Gunnison, Colorado. These pegmatites were studied and mapped at various times in 1942, 1943, and 1944 by geologists of the U. S. Geological Survey.

The three pegmatite bodies, designated the No. 1, No. 2 and No. 3 dikes, strike N. 56° E., across the schistosity of the meta-diorite wall rock, and have a general dip of 30° to 35° SE. The No. 1 dike has an exposed length of about 900 feet and a maximum thickness of 20 feet. The other dikes are not as long but are as thick or thicker. The general plunge of the No. 1 dike probably is 22° S. 28° E., and so far as is known the ore concentrations beneath structural rolls in the hanging-wall contact are parallel to this plunge.

Well-defined mineralogical and textural zones, recognized by contrasts in kinds and proportions of component minerals, are characteristic of these pegmatites. The zones are nearly parallel to the walls, and in general conform to the structure of the pegmatite bodies.

Lepidolite and microlite are the economically important minerals. These commonly are associated with quartz, cleavelandite, topaz, and beryl. Lithia, tourmaline, microcline, muscovite, zinnwaldite, biotite, fluorite, gahnite, betafite, garnet, columbite, and monazite also occur in these pegmatites, but in different zones.

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TIN AND TUNGSTEN DEPOSITS OF FRENCH MOROCCA.

E. T. HECK.

The only known deposits of tin and tungsten ores in French Morocco are located near Oulmes some seventy-five miles east of Casablanca.

The mineralized area at the El Karit tin deposit is confined to a zone of sedimentary rock along the northwest side of a granite boss. The tin occurs as cassiterite in and along quartz veins. The deposit has been worked to some extent and the presence of ore has been demonstrated over an area 2.5 to 3 miles long and 800 to 1600 feet wide.

About 3 miles southwest of the El Karit deposit is another mineralized area known as the El Zguit tungsten deposit. The ore occurs as wolframite, ferberite, and scheelite, along the margins of a few large quartz veins. The only production from the deposit has been from exploratory trenching. Most of the work has been done on two veins and mineralization has been found over a length of possibly two miles.

Both deposits are judged to be of commercial grade.

COMPOSITE PEGMATITES OF THE FRANKLIN-SYLVA MICA DISTRICT, NORTH CAROLINA.

E. WILLIAM HEINRICH.

Granite occurs in eleven mica-bearing pegmatites in the Franklin-Sylva district, North Carolina. In some it is flanked by later pegmatite, but in others it appears to have been intruded along the central part of the pegmatite during the final stages of pegmatite consolidation. Granite also occurs as inclusions and as narrow dikes that cut across the mica deposits. Both rocks appear to be related in origin to the large masses of Whiteside granite that lie along the southeast side of the mica district.

A PORTABLE DIFFERENTIAL THERMAL ANALYSIS UNIT FOR BAUXITE EXPLORATION.[1]

STERLING B. HENDRICKS, SAMUEL S. GOLDICH, AND REUBEN A. NELSON.

A small differential thermal analysis unit that embodies the fundamental features of larger laboratory models is designed for field exploration for bauxite and related materials. The apparatus, requiring only a source of electrical power, combines portability with ease of operation and rapid analysis. The portable unit is suitable for quantitative work and has been successfully applied in bauxite exploration on the island of Hispaniola.

THE STRUCTURAL RELATIONS OF THE UPPER MISSISSIPPI VALLEY ZINC-LEAD DISTRICT.[2]

ALLEN V. HEYL, JR. AND ALLEN F. AGNEW.

The district includes southwestern Wisconsin and adjacent parts of Illinois and Iowa.

The immediate rock succession is middle Ordovician limestones and dolomites, with subordinate shales.

The probable mineral paragenesis is quartz, dolomite, pyrite, sphalerite, galena, marcasite, barite, chalcopyrite, and calcite.

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The district is on the southwest limb of the Wisconsin arch, which gives a general southwest dip to the rocks. Superimposed upon this regional structure are broad, gently dipping eastward-striking folds and northwestward-trending basins. The eastward-striking folds are thought to have been formed by north-directed forces as the northern limbs dip more steeply than the southern ones. Minor folds, with an amplitude of 20 to 70 feet, that are subsidiary to the broad eastward-striking folds, form prominent local structures.

At least two types of faulting are recognized, reverse faults and vertical tear faults. Nearly flat bedding plane faults in the basal incompetent Galena beds steepen upward in the competent beds to about 45°. They, in general, are confined to the limbs of the basins, and tend to swing around the basins to form arcs or ellipses. The tear faults strike northwest or north and cut the fold structures.

The zinc-lead ore bodies border the subsidiary eastward-striking folds and their localization is controlled by the reverse faults. The ore fills the faults and tends to spread in "flats" along the bedding planes in the footwall. Ore is also found along nearly vertical joints or minor reverse faults that parallel the axes of the northwestward-trending basins.

All structures are assigned either to a north-directed or southwest-directed forces or a combination of both. They form a pattern consistent throughout the district; this, plus their magnitude, excludes the older explanation of collapse. Minor thinning of the beds by solution and replacement occurs.

QUARTZ CRYSTAL IN BRAZIL.

W. D. JOHNSTON, JR. AND ROBERT D. BUTLER.

The peak production of Brazilian quartz crystal was reached in 1943 when 2,411 metric tons were exported. Minas Gerais, Goiaz, and Bahia are the principal producing states. Minor quantities are obtained from Espirito Santo and Northeastern Brazil.

Primary veins and pegmatites yield secondary deposits of eluvial, colluvial, and alluvial origin. The veins range in form from tabular or lenticular bodies, pipes and pockets to composite lodes and bedded masses. The mineralogy is simple; accessory minerals are few and rare. A small proportion of clear crystals, occurring in vugs within the vein masses of milky quartz, furnishes the commercial product. Filling, rather than replacement, is believed to be the dominant emplacement process.

Pegmatites yield a little commercial quartz. Both residual (eluvial) and water-laid (alluvial) quartz deposits are economically important.

Crystals range up to 40 metric tons in weight; those of 1 to 5 tons occur in many deposits. Quartz from every locality studied is twinned on both the Brazil and Dauphine laws. Phantoms are abundant.

Field studies reveal little difference between the final quartz from some pegmatites and that from veins. It is inferred that the veins may grade into pegmatites at depth and that both are products of the same mineralogenic epoch. Present evidence does not justify a closer dating for the formation of the veins and pegmatites than the early Paleozoic.

TERTIARY IRON ORE IN TRIASSIC COLLAPSE BRECCIA.[1]

VINCENT C. KELLEY.

The deposit is six miles north of Capitan, New Mexico, in nearly flat-lying limestone of the San Andres formation (Permian) and near the west end of the large early Tertiary aplite intrusive of the Capitan Mountains. The ore, which is largely magnetite, forms nearly a ring about 1,300 feet in diameter; the average width of outcrop is 100 feet. Although only two very small sills of aplite crop out near the

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deposit, an unusually large quantity of silicates has formed in the limestone, especially inside the ring of ore. The principal silicate minerals are epidote, phlogopite, and tremolite which are arranged in concentric zones outward in the order given. Magnetite forms the fourth or outer zone. All of the minerals are present in the inner zone, but the characterizing mineral of a zone is not present in an outer zone. The deposits, which are genetically related to the intrusive, are located in a secondary breccia in the limestone. Solution by ground water, probably in early Triassic time, created a sponge-like cavernous condition in the limestone which crushed gradually to form what is termed a collapse breccia.

PLANT MICROFOSSILS FROM ILLINOIS COALS.[1]

R. M. KOSANKE.

Plant microfossils isolated from coal by the maceration process have been under investigation for the past two and one-half years. Nearly 500 macerations have been run on the coals from the Pennsylvanian of Illinois. The present investigation deals entirely with the microspores, isospores, and prepollen. Megaspores have been isolated and residue reserves saved.

The best general results in isolating plant microfossils from coal have been obtained with Schulze's solution followed by potassium hydroxide. The spores are stained in a concentrated solution of safranin in water and destained in alcohol in preparation for diaphane mounting.

The vertical and lateral distributions of the various genera and species have been determined. Numerous new species and a few new genera have been found. It seems possible to correlate most of the commercially important coal beds. Correlations have not been based on any one species but rather on the characteristic assemblage and zonation of spores found in the various coal beds. In addition to being a valuable aid in correlation, the study has revealed, so far as affinities of isolated spores are known, the vegetation that existed during the various coal formation periods.

In conclusion it may be stated that correlation of Illinois coal beds, and the determination of the general type of vegetation present within the coals, are possible in well organized studies of this nature.

FOUNDATION EXPLORATION AND GEOLOGIC STUDIES AT CHEROKEE AND DOUGLAS DAMS, TENNESSEE.[2]

ROBERT A. LAURENCE.

Cherokee and Douglas Dams were built by the Tennessee Valley Authority, under a war emergency schedule permitting only twenty and thirteen months construction periods, respectively. Both rest on foundations consisting largely of calcareous rocks. Therefore, interpretation of geologic features as related to foundation conditions was of prime importance to the construction staff.

At both sites, foundation defects were directly controlled by minor features of stratigraphy and geologic structure. At Cherokee these were (1) a network of solution channels along joints in two limestone beds in a shale formation, especially at and near minor folds and cross-faults, (2) local deep weathering of calcareous shale beds, especially near the same minor structures, and (3) cavernous dolomite beds on a divide forming the reservoir rim.

Principal defects encountered at the Douglas site were (1) extensive solution openings under the river channel, especially along strike joints, (2) bedding-plane caves developed above thin cherty or shaly beds in the abutments, and (3) deep weathering in and near a deposit of volcanic ash and dolomite filling a pre-Chazyan sink hole.

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Exploration, largely by diamond drills and large-diameter calyx drills, was carried on for six months before construction, as well as during much of the construction period, and invaluable geologic data were obtained from grout holes and daily observations in the excavated areas. Final limits of excavation, and methods and extent of foundation and rim treatment were adapted to the geological conditions to provide safe and water-tight structures.

OCCURRENCE AND DISTRIBUTION OF IRON MINERALS IN PENNSYLVANIA FIRE CLAYS.

EARL LEATHAM.

Millions of tons of flint fire clay occurring in Clearfield and adjoining counties of Pennsylvania are of no industrial value because of the high content of iron minerals. The amount of iron minerals expressed as Fe_2O_3 usually varies between 8 and 15 per cent. A study of the occurrence and distribution of the iron minerals was made to evaluate the possibility of removing the iron by beneficiation.

The contact print method,[1] as described by Gregorie Gutzeit, was used because it was simple and rapid. Gelatin-coated white paper treated with the proper reagents was pressed against a polished surface of clay. A colored iron compound was formed opposite each iron mineral.

It was found that most of the iron occurred as siderite with minor amounts of pyrite or marcasite. There was marked variation in the size of the siderite crystals from different parts of the area. In one relatively small area, the siderite crystals averaged 0.5 millimeter in diameter. Probably this clay could be beneficiated. Throughout the greater part of the area, the diameter of the siderite crystals averaged less than 0.02 millimeter. It is doubtful if such clay could be beneficiated commercially.

THE ILLINOIS GEOLOGICAL SURVEY'S ACTIVITIES IN WAR AND PEACE.

MORRIS M. LEIGHTON.

This paper will describe the unusual research program of the Illinois Geological Survey during the war and now with the resumption of peace, its modification to serve a State that is highly industrialized and has extensive mineral resources.

Some thirty projects were carried on which had direct bearing on the prosecution of the war by the government and by industry. Nineteen of these concerned geology primarily, eight variously involved the combined fields of geology, geophysics, chemistry, chemical engineering, and petroleum engineering, four were primarily chemistry, and one was topographic mapping.

The peace-time program of the Survey will differ from the war-time program in only certain special respects. Fundamental work will now receive greater emphasis in stratigraphy, paleontology, paleobotany, clay mineralogy, coal petrography, x-ray and spectrography—although not all of this work was suspended during the war—and chemical studies of the nature of coal, and certain chemical and physical technologic studies will be resumed. Mineral economics has been reemphasized during the war period and this will continue. Educational extension work among teachers of high school science and the citizenry will also be resumed.

This unusual program among State surveys was made possible by a period of 10 years of expansion and development before 1942, during which the geological resources section of the Survey was broadened, geochemistry, geophysics, and mineral economics were added, larger provision was made for dissemination of information, and two new buildings—a Natural Resources Building and an Applied Research Laboratory—were completed, equipped and occupied within the year before Pearl Harbor.

[1] Gregorie Gutzeit, "Determination and Localization of Metallic Minerals by the Contact Print Method," A.I.M.E. Technical Publication No. 1457, 1942.

ALTERATION AND STRUCTURE IN THE EAST TINTIC DISTRICT, UTAH.[1]

T. S. LOVERING, W. M. STOLL, A. H. WADSWORTH, H. C. WAGNER, B. F. STRINGHAM, L. S. HILPERT, J. F. SMITH, AND ALBERTO TERRONES.

The East Tintic district is two miles east of Eureka, Utah, and is noteworthy for its large blind limestone replacement ore bodies lying well below strongly altered quartz latite flows. Cambrian quartzite, shale and limestone that were cut alternately by steep angle and low angle faults of at least three tectonic episodes separated by intervals of folding were deeply eroded before the lava was extruded. Minor movement along the earlier fractures subsequently accompanied intrusion of quartz monzonite porphyry and preceded the deposition of ore. The character of the basement rock and the many tectonic events makes the area ideal for studying the processes of alteration and their duration. Five major stages are recognized: (1) The early barren stage, characterized by extensive hydrothermal dolomite and minor chloritic alteration, and contemporaneous with the earliest volcanism; (2) The mid-barren stage, a dominantly argillic alteration preceding and accompanying the first intrusions of quartz monzonite porphyry and characterized by widespread dickite, kaolinite, halloysite, beidellite and rutile, with quartz and alunite locally abundant; (3) The late barren stage, an allophane-quartz-barite alteration that immediately preceded ore and was almost restricted to the channels of mineralization deposition open during the ore stage; (4) The productive stage, chiefly marked by ore deposition, sericite, and hydromica; (5) The weathering stage, with montmorillonite as the characteristic mineral.

The leaching, transfer and redeposition in different form of rock constituents can be traced with confidence in several phases of the alteration, but no such immediate source is evident for some of the material added to the rocks in certain types of alteration. The magnesium for hydrothermal dolomite is probably magmatic; the acid radicles in the solutions that effected the argillic alteration may be the only magmatic contribution during the mid-barren stage; barium, sulphur dioxide, and carbon dioxide are the chief constituents that can be ascribed to the magma during the late barren stage, but nearly all the material added during the productive stage is probably of magmatic origin.

The acid leaching of, and transfer of potash and silica from warm quartz monzonite bodies during the mid-barren stage is reflected in silicic and potassic halos around the partly argillized intrusives. The replacement of dolomite and limestone by jasperoid and ore is reflected by a calcitic replacement of the lavas above. The nearly neutral character of the ore solutions is suggested by the lack of other alteration during the formation of disseminated pyrite in the lavas above the ore bodies.

The character of the altering solutions and the sequence of alterations—(1) magnesium, (2) argillic or acid, (3) silicic and carbonic acid, (4) potassic and sulfidic—are believed to be of general occurrence in western mining districts, though the mineralogy may vary with the character of the rocks and the physical conditions that obtained during the alteration.

GENERAL PRINCIPLES OF ARTIFICIAL GROUND-WATER RECHARGE.[2]

O. E. MEINZER.

The natural subterranean reservoirs formed by the porous and permeable rocks differ from surface reservoirs chiefly in that they have complex structure and great internal resistance to the flow of water. Their full utilization requires systematic development based on the geology and hydrology of the aquifer and the

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principles of hydraulics distinctive of ground water. Recharge may be greatly increased simply by pumping from wells and thus making storage capacity available. But the rate at which any group of wells can yield water perenially is limited by their ultimate cone of depression with maximum drawdown. Further utilization of the reservoir calls for new wells at adequate distances from the old wells or artificial recharge near them. In some places large supplies have been obtained by locating wells near a stream and developing a steep hydraulic gradient from the stream to the wells.

In an artesian aquifer geologic study with test drilling is needed to determine the actual intake area and its structural relations to the pumped wells, as a clay bed, fault, or other barrier may intervene between the assumed intake area and the wells. If the capacity of an artesian aquifer to carry water to the wells under maximum drawdown is less than the potential recharge in the intake area, further utilization can be accomplished only by recharge through wells penetrating the confining bed or by sinking production wells nearer the intake to steepen the hydraulic gradient.

Artificial recharge requires an effective process for getting the surface water into the saturated part of the aquifer—either by surface infiltration or through wells. The major requirement, in addition to a permeable terrane, is clean water that will not clog the intake or practicable means of periodically cleaning it. Various processes are now in use with constantly developing technique.

POST-PALEOZOIC MINERALIZATION IN PENNSYLVANIA.

W. M. MYERS.

Many scattered instances of metalliferous mineralization are known in Central Pennsylvania. Some of these deposits have been mined in the past and have served as small sources of metal. They have never developed into large producers of commercial significance nor have they been explored extensively. The most common mineralization is galena-sphalerite associated with minor amounts of pyrite and chalcopyrite. The common gangue minerals are calcite and barite. At the outcrop typical oxidation products are found although the depth of oxidation is small and unaltered sulphides are found close to the surface. Such deposits are well developed in the Ordovician limestones in Sinking Valley, Blair County, and in the Tuscarora sandstone near Bellefonte, Centre County. They occur typically in steeply dipping fractures or fault planes of unknown depth in the immediate vicinity of major faults. In the sandstone the ore minerals have served as a cement which has bonded the angular fragments of country rock producing a breccia. The presence of a thin soil overburden and the absence of open workings have made examination difficult and valuation of possibilities impossible. These veinlike deposits show the common criteria of hydrothermal origin except there are no known igneous rocks in the area. Peridotite dikes, known to be post-Pennsylvanian in age, have been found in southwestern Pennsylvania intersecting coal strata. Evidence suggests that same Paleozoic sediments have been intruded to an unknown degree by igneous rocks and processes of differentiation may have supplied solutions that have produced concentrations of metallic sulphides.

STUDIES OF MINERAL SULPHO-SALTS: XI—WITTICHENITE (KLAPROTHITE).

E. W. NUFFIELD.

Wittichenite and klaprothite were undistinguished under the name Kupferwismutherz, later wittichenite, until Petersen (1868–9) restricted wittichenite to the mineral with the composition $3Cu_2S.Bi_2S_3$, and proposed klaprothite for a mineral resembling emplectite ($Cu_2S.Bi_2S_3$) which gave a composition near $3Cu_2S.2Bi_2S_3$. X-ray examination of numerous specimens labelled wittichenite or klaprothite from

the Wittichen mines, Baden, gave only wittichenite and emplectite. The wittichenite pattern is identical with that given by the homogeneous fusion product $3Cu_2S.Bi_2S_3$. A crystal, part of which gave the wittichenite pattern, yielded the orthorhombic unit cell with $a = 7.66$, $b = 10.31$, $c = 6.69$ kX; space-group $P2_12_12_1$; contents $2[3Cu_2S.Bi_2S_3]$. Many published observations on "klaprothite" evidently refer to wittichenite and it appears that Petersen's analysed "klaprothite" was a mixture of wittichenite and emplectite.

GENERAL STRATIGRAPHY OF THE EAST TENNESSEE ZINC DEPOSITS.

CHARLES R. L. ODER AND HOWARD W. MILLER

Zinc deposits occur in nearly every county in East Tennessee in Cambrian and Ordovician rocks.

Ore has been produced from the Shady, Rome, Maynardville, Copper Ridge, and Kingsport formations.

The Shady dolomite has yielded "carbonate" ore at Embreeville. It is composed of 1,000 feet of light gray, coarsely crystalline dolomite and dark gray, fine grained dolomite and limestone.

The Rome formation includes about 1,000 feet of variegated shales and red sandstones. Sphalerite sometimes occurs in thin calcareous zones in the upper shales.

The Maynardville limestone contains 60 to 250 feet of dark gray, fine grained limestone and dolomite some of which shows argillaceous laminae.

The Copper Ridge formation usually consists of 900 to 1,200 feet of dark sugary and light gray, fine grained, cherty dolomite with considerable limestone in the eastern areas.

Stratigraphic studies have proved valuable in the important Mascot-Jefferson City mining district. The following divisions of the Kingsport formation have been described, in descending order: (1) 101 to 135 feet of light and dark gray dolomite with a little limestone and numerous arenaceous and cherty horizons, (2) 44 to 50 feet of very light gray dolomite with concentric chert nodules, (3) 33 to 38 feet of light and dark gray dolomite and a little limestone, sometimes altered to crystalline dolomite, (4) 178 to 216 feet of brown limestone, frequently altered to crystalline dolomite, a moderate amount of light and dark gray dolomite, and numerous cherts.

Some crystalline dolomites in the Kingsport are believed to represent replacement of limestone.

STRUCTURAL AND MINERALOGICAL CHARACTERISTICS OF SOUTH DAKOTA PEGMATITES.[1]

LINCOLN R. PAGE.

Detailed structural and economic investigations of over one hundred and forty South Dakota pegmatites by members of the Geological Survey in 1939–45 have shown that many of the pegmatites exhibit similar structural and mineralogical characteristics. These characteristics have a direct bearing on the origin of pegmatites as well as on mining practice.

The important structural features of these pegmatites are (1) external shape, (2) zoning, (3) gneissic banding, (4) orientation of minerals, and (5) internal cross structures. These structural features show a definite relation to the planar and linear structures of the wall rocks. In most pegmatites concentrations of minerals can be related to these structures.

The distribution of minerals in all the pegmatites studied seems to follow a general sequence related to the internal zoning, but the abundance of any particular

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mineral is controlled by the composition of the liquid from which the pegmatite formed and the history of crystallization. Variations in the chemical composition of plagioclase, beryl, and columbite-tantalite have been noted in different parts of a pegmatite and appear to be systematic when related to zonal structure. These variations in chemical composition may be accompanied by differences in physical form and color. The alteration of spodumene and the consequent decrease in lithia content appear to be related in part to its structural position in a pegmatite. Preliminary investigations suggest that perthite and microcline, as well as flat and "A" books of muscovite also have a preferred structural position.

CONTACT METAMORPHIC DEPOSITS OF CASSITERITE IN CALIFORNIA.[1]

LINCOLN R. PAGE.

Small quantities of cassiterite have been produced at the Evening Star mine in the Cima district, San Bernadino County, and from the Meeke mine in the Gorman district, Kern County, California. These deposits are of the contact metamorphic type and were investigated by the Geological Survey in 1940–44.

The Evening Star deposit is in dolomite and dolomitic marbles near an intrusive body of quartz monzonite. Cassiterite occurs with scheelite, chalcopyrite, sphalerite, pyrite, and magnetite as disseminated grains, euhedral crystals, and massive aggregates in tremolite-serpentine-calcite rock. Near the surface hematite, limonite, malachite, chrysocolla, melaconite, calamine, and other secondary zinc minerals are common. Talc is associated with brecciated cassiterite along shear zones that cut the ore.

The irregular, lenticular ore bodies of the Evening Star deposit were formed by replacement of favorable beds along and outward from a mineralized zone which is 120 feet long and up to 20 feet wide.

In the Gorman district cassiterite has been identified in six small, irregular bodies of iron-rich tactite and limonitic gossan that occur in recrystallized limestone at the margin of a granite intrusive. The primary ore contains cassiterite, scheelite, powellite, pyrite, chalcopyrite, arsenopyrite, molybdenite, magnetite, epidote, tourmaline, ludwigite, amphibole, garnet, phlogopite, calcite, and quartz, though not all of these minerals occur in each deposit. The gossanin deposits such as the Meeke also contain malachite, chrysocolla, jarosite, gypsum, chalcedony, opal, cuprite, native copper, and clay minerals.

INVESTIGATION IN PETROGRAPHIC METHODS OF COAL ANALYSIS.[2]

BRYAN C. PARKS AND GILBERT H. CADY.

Analysis of columns of bituminous coal to determine composition of banded ingredients is a rather common routine in some laboratories. However, such analyses restricted to complete bed coal samples, fairly difficult to secure, give information more fundamental than utilitarian in value. General usefulness of petrographic methods of banded ingredient analysis requires application to broken coal of commercial sizes. The technique developed and used by the Illinois Geological Survey and the results obtained are described. These results are supported by four preliminary or concurrent accomplishments:

1. Development of a crushing technique using roll crushers to separate the banded ingredients into discrete particles predominantly of megascopic size range.
2. Development of size distribution curves for ascertaining distribution of banded ingredients in fine sizes extremely difficult to analyze megascopically.

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3. Determination that micro-vitrain from clarain contributed but little to the quantity of analytical vitrain when the approved sample-preparation methods were used.

4. Determination that under commercial methods of coal preparation response of banded ingredients to changes in density of gravity-separation fluids was small.

HYDROTHERMAL ALTERATION IN THE CASTLE DOME COPPER DEPOSIT.[1]

N. P. PETERSON, C. M. GILBERT, AND G. L. QUICK.

The Castle Dome copper deposit, near Miami, Arizona, is in a body of quartz monzonite much older than the mineralization. It is of the low grade "porphyry" type in which the protore contained about 0.3 percent copper present as chalcopyrite. The chalcopyrite is associated with a set of narrow, closely spaced, generally parallel quartz-pyrite veins and occurs both within the veins and disseminated in the wall rock.

Hydrothermal alteration of the quartz monzonite consists of three phases. Very weak propylitic alteration of biotite and plagioclase occurs in the marginal part of the mineralized area. Where mineralization is stronger most of the plagioclase and a little orthoclase and biotite are replaced by allophane and a montmorillonite-type clay resembling beidellite. The general appearance of the quartz monzonite is little changed by this clay alteration. The third phase is localized along the quartz-pyrite veins where the wall rock commonly as much as an inch from the vein is replaced by quartz and sericite. In contrast to the localization of the quartz-sericite alteration along veins, the clay alteration is general and can be seen between veins wherever the rock is not completely sericitized. Thus these two types of alteration cannot be separated areally. The most intense clay alteration together with moderate quartz-sericite alteration occurs in the ore body, whereas the strongest quartz-sericite alteration, where pyrite veins are largest and most numerous, is in a zone along the north side of the ore body.

REDUCTION OF SULPHATES IN OIL-FIELD SALT WATER.

F. B. PLUMMER.

Bastin and others have demonstrated the presence of sulphate-reducing bacteria in oil wells producing salt water. Analyses show that, at 125 degrees F., bacteria alone reduce sulphates in east Texas salt water by 3 percent in 30 days, forming principally hydrogen sulphide and sodium and calcium hydroxide. The hydrogen sulphide reacts with soluble iron compounds to produce iron sulphide in the absence of oxygen, and ferric hydroxide where oxygen or air is present. Where iron or other metals and iron sulphide are already in the water containing the bacteria, the reduction of the sulphates is complete in 30 days or less; where magnesium is present, reduction is complete in 15 days. The effects of changes in temperature, of different metallic substances, of different bactericides, and of concentration of bactericides on sulphate reduction is described in detail and illustrated by tables and curves. The significance of sulphate reduction on corrosive properties of oil-field water, on the forming of sediments, and on certain geologic processes, and especially the part played by bacteria in the formation of concretions, are discussed briefly.

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INFLUENCE OF ROCK AND SOIL COMPOSITION ON PERFORMANCE OF METALLIC MINE DETECTORS.[1]

RALPH ROBERTS, FOR THE STAFF OF THE MILITARY GEOLOGY UNIT.

In foreign combat areas Allied troops found that their metallic mine detector was not effective over certain rocks and soils. Accordingly, the Military Geology Unit was asked by the Chief of Engineers to cooperate with the Engineer Board, Fort Belvoir, in correlating detector performance with rock and soil types, so that performance in enemy-held terrain could be predicted.

Field studies of rocks and soils in the Washington, D. C. area were made by geologist-pedologist-engineer teams using the detector. In addition, soil samples from many parts of the world were tested with a detector modified for laboratory use. The samples showed a wide range in reactivity, depending upon their parent rocks and the mineralogic changes which took place during weathering.

Field and laboratory tests showed that the performance of the metallic mine detector is closely related to soil and rock type. Therefore, knowing these for any area, the performance of the instrument is predictable, and "performance maps" can be constructed in advance of military operations. It was shown that the detector could be expected to perform effectively in the most probable combat areas in Japan and China.

The laboratory instrument should be of value in geologic and mineralogic research. It is compact and light, and can be used in the field to measure the magnetic susceptibilities of most minerals, rocks, and soils.

MILITARY WATER SUPPLY.[2]

A. NELSON SAYRE.

The trained ground-water geologist can render important service to the armed forces by providing water-supply intelligence for planning on the operational and on the strategic level and by acting as field adviser to the Engineer troops charged with supplying water.

The importance of these services varies somewhat with local conditions, the nature of the operation, the training of the Engineer troops, and other factors. Combat operations usually require ½ gallon to 5 gallons of water per capita per day. In humid regions, this quantity of water is ordinarily obtained from streams, although in some cases it necessitates hauling water long distances over roads that are already overcrowded. However, such practices are at times unavoidable under field conditions.

In arid regions or in humid regions where large supplies are required for hospitals and other base installations, securing adequate, safe water supplies is a difficult problem and often requires considerable skill, special equipment and material. Therefore the planning staffs must have the best information possible well in advance of the proposed operation. The geologist assembles and evaluates all of the available engineering and geologic data, studies operational photography to determine the nature of the soil and underlying rocks and their relation to water supply as revealed by topography, drainage, rock outcrops, etc. He is thus enabled to furnish surprisingly accurate water supply intelligence for consideration in planning.

He can also be helpful as a consultant to the construction engineers during the operations by locating well sites, evaluating springs and stream supplies and by advising or instructing troops on methods of well construction, development and pumping.

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PLANT MICROFOSSIL INVESTIGATIONS IN WESTERN COALS—A PROGRESS REPORT.[1]

JAMES M. SCHOPF AND AUREAL T. CROSS.

Plant microfossils provide a means of effectively supplementing other sources of geologic information regarding the precise local identity of coal beds. Studies are being carried on in the Kemmerer coal field in Wyoming, the Paonia district in Colorado, and in the Coos Bay coal field in southwestern Oregon. The present paper indicates the variety of microfossil material available from these Cretaceous and early Tertiary coal deposits, and the practical problems that have bearing on the conduct of such work.

GROSS PETROLOGY OF COAL IN RELATION TO EXPLORATION OF COAL RESERVES BY DIAMOND DRILLING.

JAMES M. SCHOPF AND HENRY L. SMITH.

Methods which have been evolved in dealing with coal cores in the petrographic laboratory of the Bureau of Mines are discussed. Approximately 2000 feet of selected portions of cores consisting predominantly of coal, have been studied in connection with explorational drilling of strategic coal reserves during the war.

A major objective of this work has been to provide a reasonably detailed factual record of the character and variation in coal recovered by drilling. This information has proved of considerable value since it serves to coordinate data based on field operations with laboratory analyses and tests. Selection of samples according to appropriate lithologic subdivisions in the coal and the rejection of proper classes of impurities is particularly important.

Frequently there is a marked contrast in the observable lithologic features of the coal due solely to the differing conditions of field and laboratory. Megascopic petrology in the laboratory is readily determined and of practical significance; it is supplementary to more detailed observations made by use of the microscope.

Data obtained from certain coal cores are used for illustration of the methods.

HYDROTHERMAL ALTERATION IN THE SAN MANUEL COPPER DEPOSIT, ARIZONA.[2]

GEORGE M. SCHWARTZ.

The San Manuel Copper Exploration is about one mile south of Tiger and 35 miles southeast of the copper deposit at Ray, Arizona.

The mineralized rock is principally quartz monzonite (Oracle Granite) of pre-Cambrian age and monzonite porphyry presumably Tertiary in age. Most of the copper mineralization is buried beneath a cover of Gila conglomerate.

Hydrothermal alteration in the vicinity of the deposit is intense and at least four types may be distinguished and mapped.

Type 1 is characterized at the surface by a light gray color and by alunite and kaolinite. This zone is known only from surface exposures and most of the rock is monzonite porphyry. The original minerals and texture are largely destroyed but shadows remain in thin-section. Kaolinite and alunite are most abundant but hydromuscovite, allophane, rutile, jarosite, hematite and limonite are common and chlorite, potash clay, dickite, and halloysite were recognized.

Type 2 occurs in a zone nearly surrounding Type 1 and is characterized by high pyrite at depth and hematite where oxidized. The alteration is intense but the original texture is preserved. The characteristic minerals in unweathered rock are pyrite and hydromuscovite with lesser sericite, chlorite, leucoxene, rutile, allophane,

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[2] Published by permission of the Director, United States Geological Survey.

kaolinite, hydrobiotite and some montmorillonite and dickite in weathered specimens.

Type 3 occurs in a tabular zone along the south side of Type 2 which dips steeply southward. The characteristic minerals below the zone of weathering are sericite, pyrite and chalcopyrite. Common are chlorite, rutile, quartz, hydromuscovite, kaolinite, hydrobiotite, allophane, potash clay, and more rarely alunite and adularia.

Type 4 is a less altered zone but the alteration is mineralogically complex. The rock is dark gray owing to much finely disseminated biotite and hydrobiotite in the groundmass. Biotite altered to hydrobiotite, nontronite, chlorite, sericite, rutile, leucoxene, epidote and calcite. Plagioclase shows partial alteration to sericite, hydromuscovite, potash clay, beidellite, and chlorite. Small amounts of pyrite and chalcopyrite are uniformly present. On the north side of the area this alteration is characterized by abundant epidote and zoisite.

AN INTRODUCTORY STATEMENT REGARDING POLLEN ANALYSIS.

PAUL B. SEARS.

The outer coat of the spores of many vascular plants is resistant to decay. Such coats also generally exhibit characteristic patterns which, together with size and shape, are of great assistance in identifying the plants that produced them. Generic identification is most feasible and specific differences may be obscure.

Many types of spores, including the pollen grains of a number of genera of seed plants, are produced in great quantities and disseminated by wind. Under appropriate conditions of sedimentation, and notably in bog silts and peats, they are well preserved, and can be subsequently prepared for microscopic study.

Subjected to statistical examination—an operation known as pollen analysis—these spores shed light on the trend of vegetational history during the accumulation of particular sediments. Inferences regarding the climatic history of a region may be made by integration of such information.

The method of pollen analysis has been most extensively applied to post-Pleistocene sediments. It has also proved of value in study of interglacial deposits, in the correlation of archaeological materials, faunal remnants, and the relative "dating" of geomorphological events. Somewhat similar methods are now being applied to the study of coal. Thus methods originally developed for study of recent changes in vegetation and climate now have more diversified significance.

MODERN ASPECTS OF GEOCHEMISTRY AND THEIR APPLICATION TO ECONOMIC GEOLOGY.[1]

TAISIA STADNICHENKO.

Previous to the development of atomic physics and the knowledge of laws of crystal chemistry, geochemistry depended mostly on descriptive mineralogy and the data derived from chemical analyses of rocks and minerals collected in the different parts of lithosphere, hydrosphere and atmosphere. The recognition of the reality of concept of atom-elements, systematic studies of their structures, and the laws of crystal chemistry gave a new impetus to examination of geochemical processes. While the frequency of an element in the Cosmos depends on structure of its atomic nucleus, the distribution, migration, accumulation, and dispersion of chemical elements and their compounds are determined by the electrons of the outer shells. The behavior of atom-element in crystal lattice is governed by laws of geometric equilibrium and a crystal represents a complex electromagnetic field which is determined by energy of the system.

The laws of atomic lattices explain such well known associations as: Cu, Co, Ni and especially Cu and Fe; Zn, Fe, Mn; constant presence of Au in Ag; also less

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familiar series of Cd and In; Pt group with Fe, Cu, As and Mo; presence of Re in Pt ores and Mo compounds. The geochemical processes leading to separation of Co from Ni and Fe is a complex function of such variables as: atomic weight, atomic number, co-ordination number, energy of the crystal lattices, and ionic radii. In the last 20 years in many countries particularly in Russia application of the new principles to study of geochemical processes helped to formulate the important rules of geochemical associations, to forecast distribution and accumulation of the various elements, and to suggest better means in solution of prospecting, mining, and technological problems.

PETROGRAPHIC COMPARISON OF PLIOCENE AND PLEISTOCENE VOLCANIC ASH FROM WESTERN KANSAS.

ADA SWINEFORD AND JOHN C. FRYE.

Lenticular, discontinuous deposits of volcanic ash occur in western Kansas in at least two stratigraphic positions within the Pliocene Ogallala formation and in one or more within the Pleistocene strata. The ash, which is extensively mined, attains a known maximum thickness of more than 20 feet. In an attempt to determine the feasibility of stratigraphic correlation by minor petrographic differences in the volcanic ash, a study was made of 30 samples from eight Pliocene localities and 24 samples from ten Pleistocene localities. Sieve analyses showed no consistent difference among the several samples even though a few zones of Pliocene ash were coarser than any sample of Pleistocene age. A color comparison of the fraction finer than 62 microns showed a consistent difference. Color differences are less pronounced in the coarser grades. A refractive index of about 1.501 is common to all Kansas samples studied except those from one Pliocene locality (R. I. ca. 1.506). The most prominent difference between the ash of the two ages is the presence of numerous elongated fluid inclusions in many shards in the Pleistocene samples. These are rare in the Pliocene ash, most of the particles of which are either clear or clouded with mineral and small equidimensional fluid inclusions. Chemical analyses of 27 samples show the Pliocene ash to be generally higher in iron. A sample of Pliocene ash from Hemphill County, Texas, showed most characteristics typical of Kansas Pliocene samples, but had a refractive index of about 1.496.

PRELIMINARY CHEMICAL CORRELATION OF CHROMITE WITH THE CONTAINING ROCKS.[1]

T. P. THAYER.

Chromite investigations of the Geological Survey since 1939 indicate that economic deposits of chromite rich in normative spinel ($(Mg,Fe)Al_2O_4$) occur in peridotites which are closely associated with gabbro; high-chrome chromites occur in feldspar-free peridotites; and chromites rich in both normative chromite ($(Mg,Fe)Cr_2O_4$) and magnetite (Fe_3O_4) are found in the pyroxene-rich stratiform complexes. Reaction of high-alumina chromite with diopsidic gabbro to form anorthite, olivine, and enstatite is described, and some probable equilibria between chromite and silicate minerals are discussed.

A plot of 60 complete analyses on a triangular prism of composition shows that chromites from different geologic provinces in the Western Hemisphere vary consistently and fall in overlapping, but distinct, fields. The chromites of the Caribbean Province, which occur in dunite and troctolite, have the general formula $Cr_{25-80}Al_{15-75}Mt_{1-8}(Mg_{65-75})$ and average about $Cr_{50}Al_{47}(Mg_{70})$. The chromites of the Pacific Coast, which occur in dunite and saxonite, average about $Cr_{70}Al_{24}(Mg_{60})$ in the range $Cr_{60-77}Al_{16-35}Mt_{3-12}(Mg_{45-75})$. The chromites of the Stillwater complex, like the stratiform Bushveld ores, occur in bronzite-rich rocks and are richer in iron; they average about $Cr_{60}Al_{32}(Mg_{52})$, and cover the range $Cr_{52-69}Al_{26-39}Mt_{5-16}(Mg_{45-61})$.

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ARTIFICIAL RECHARGE OF ARTESIAN LIMESTONE AT ORLANDO, FLORIDA.[1]

A. G. UNKLESBAY AND H. H. COOPER, JR.

The principal aquifer in the Orlando area consists of 900 feet or more of permeable artesian limestone of upper and middle Eocene age. As in most other parts of the Florida peninsula, this limestone is overlain by the Hawthorn formation of Miocene age which contains relatively impervious beds. The Hawthorn at Orlando is 45 to 100 feet thick and prevents or retards natural recharge to the limestone formations except where it is penetrated by what appear to be old sinkholes that are now filled with previous material.

Owing to the lack of adequate surface drainage, more than 175 wells have been drilled into the limestone in the Orlando area to drain streets, control lake levels, and dispose of sewage and other waste liquids. Generally the piezometric surface of the water in the principal aquifer is far enough below the land surface to allow drainage by gravity. As the limestones are cavernous, most of the wells have large capacities for draining water and seldom become clogged although a considerable amount of rubbish is carried into them.

The piezometric surface of the artesian water is conspicuously higher where drainage wells are concentrated, evidently because of recharge through the wells. However, the effect of the artificial recharge cannot be clearly differentiated from that of natural recharge. A deep-well current meter was used successfully to determine the horizons at which the polluted surface waters enter the limestone.

The investigation was made in cooperation with the Florida Geological Survey and the Corps of Engineers of the U. S. Army.

MAGNESIUM MINERALIZATION IN THE CURRANT CREEK DISTRICT, NEVADA.

CHARLES J. VITALIANO.

The Currant Creek District is in White Pine and Nye counties, Nevada, 35 miles southwest of Ely, Nevada.

The host rock for the magnesium mineralization is a bedded calcareous tuff of late Miocene or early Pliocene age, ovarlain by quartz latite and underlain in the western part of the area by basaltic andesite and dacitic rock and in the eastern part of the area by dacite. The thickness of the tuff is variable but averages 300 feet. Unaltered tuff may contain as much as 80 per cent carbonate. All beds dip gently eastward from the summit of the Horse Range, but they are broken by a number of northeasterly trending major faults and several minor faults of variable trend.

Magnesite replaces the calcareous tuffs and occurs as nodules, as veins or lenses and as disseminated grains in masses of unaltered tuff. The associated minerals are dolomite, an unamed magnesium silicate, possibly a member of the serpentine group, calcite and silica in the form of chalcedony, opal and quartz. The hard, dense, white nodules are distributed in zones, commonly a hundred or more feet in length. The lenses or veins may reach a length of 100 feet and a width of 12 feet but are generally much smaller.

The silica minerals are late and transgress the others. Magnesite is earlier than the silica minerals. Its relation to the other carbonates is not always clear but it is probably later than most of the dolomite.

The alteration is believed to have been due to ascending hot spring waters, rich in magnesia, that formed the magnesium silicate and dolomite, which were replaced in turn by magnesite. Later solutions deposited various forms of silica which cut or replaced earlier minerals.

[1] Published by permission of the Director, Geological Survey, U. S. Department of the Interior and the Director, Florida Geological Survey.

STRUCTURE OF THE ZINC-LEAD DEPOSITS OF NORTHWESTERN ILLINOIS.[1]

H. B. WILLMAN.

The major zinc-lead deposits of northwestern Illinois are linear in outline, usually 100 to 200 feet wide and as much as 1 mile long, and have an orientation consistent with the regional joint system. The ore occurs principally along zig-zag and inclined fractures "pitches," along bedding-planes "flats," in breccia zones, and disseminated. Solution of relatively soluble limestone strata underlying the Ordovician Galena dolomite appears adequate to account for the ore-bearing structures in the Graham-Ginte ore body, the only ore body now well exposed.

In the Graham-Ginte ore body the combined thickness of the "oilrock" and "glassrock" limestones, which underlie the Galena dolomite, varies as much as 20 feet. The thickness variations of the "oilrock" have been interpreted previously as sedimentary or resulting from structural incompetence, but the abrupt thinning of the limestone beds, the persistence of argillaceous and siliceous beds, the configuration of the insoluble material to joints, and the interpenetration of large blocks of "oilrock" and "glassrock," simulating styloeites, favor thinning by solution. The limestone underlying the "glassrock" is not exposed but it also may be thinned by solution.

The total vertical displacement of the beds is usually less than 10 feet and is not known to exceed 20 feet, which is no greater than the thinning resulting from solution.

Subsidence following solution explains the shallow structural trough in which the ore occurs, the fractures which converge upward above the trough, the bedding-plane openings, the brecciated "core-ground," and both the normal and reverse faults.

The local brecciation of the "pitch" and "flat" deposits before mineralization ended and the solution of limestone beds after mineralization suggests that solution, deformation, and mineralization were active contemporaneously.

APPLICATION OF PALEOECOLOGICAL METHOD TO AN EARLY TERTIARY COAL SEAM.

L. R. WILSON.

Samples of coal were collected from five exposures of a single coal seam located near Wamsutter, Wyoming. This coal is of Green River age. The samples were macerated and studied microscopically for plant spores and pollen. Tertiary coals contain many genera of modern plants. The species are probably all extinct but ecological inferences can be drawn from the present distributions of the genera. The microfossils observed in the Wamsutter coal number close to two hundred species. Counts of 1000 fossil spores and pollen from each collection were made. These give some idea of the composition of the Green River vegetation in the vicinity of the Red Desert of Wyoming. The various species of spores and pollen do not appear in the same abundance throughout the vertical extent of the seam. This fact suggests a change in the vegetative cover which might be related to topographic development or climatic variation during Green River time. In general the fossils depict a warm moist climate with phases of semi-aridness. Several species of pollen suggest an adjacent topography of considerable relief. There is a fair ecological correlation between the five exposures of coal. If the samples had been collected in short contiguous sections instead of

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at intervals through the seam, correlation of levels might have been more than approximate. With some modification the paleoecological method may be applied to Tertiary coals.

LUMINESCENT PHENOMENA AS AIDS IN THE LOCALIZATION OF MINERALS IN POLISHED SECTIONS.

HERMAN YAGODA.

On exposure to ultraviolet light a considerable number of minerals become readily discernible as a result of fluorescence or phosphorescence. The resultant optical activity is usually associated with the presence of minor constituents. The fluorescent pattern can on occasion be utilized for the estimation of the trace element causing the activity, a notable example being the estimation of the molybdenum content of scheelites. An annular cold quartz ultraviolet illuminator is described which permits the microscopic examination of fluorescing minerals in polished sections. Photomicrographs up to 150 × magnification can be secured which are serviceable for aerometric analysis and for the study of mineral intergrowths.

The phosphorescence of minerals is best studied by direct contact printing avoiding the use of optical equipment. After irradiation the polished section is immediately placed on fast panchromatic film for about two minutes. On development a permanent record is secured showing the distribution of the phosphorescing constituents. This autoluminograph will often reveal constituents emitting radiations not visible to the eye but which activate the emulsion. By utilizing color sensitive film a true color replica is recorded of the evanescent phosphorescence. Such patterns have proven useful in the study of the Franklin, N. J. mineral deposits. The autoluminographs localize the willemite (green), clinohedrite (orange), and hardystonite (purple); the accompanying calcite, franklinite and zincite are non-luminescent and are depicted as voids in the autoluminographic pattern.

The thermoluminescence of hackmanite and certain varieties of fluorite can be recorded photographically by warming the thin section on a hot stage beneath the camera.

These luminescent properties are being employed in the study of the distribution of dust particles in lung tissue utilizing fluorescent hyalite opal and willemite as tracers for free and combined silica, respectively.

ADDITIONAL ABSTRACTS

The papers represented by the following abstracts will not be presented at the sessions of the Society of Economic Geologists, but at sessions sponsored by affiliated societies. They have been offered, however, through the sponsorship of this Society.

ENGINEERING APPLICATIONS OF AERIAL RECONNAISSANCE.

DONALD J. BELCHER.

The development of aerial photography and the extensive coverage that has been accomplished in recent years has stimulated the use of airphotos to facilitate engineering planning and construction. The basis of this phase of development has been the identification of features that bear a relationship to the texture of the soil pattern although they include such elements as land form, drainage, soil color, erosion, and vegetative cover. Land form identification does much toward establishing general conditions of soil depth and texture, while surface drainage indicates relative permeability. Gullies assume various shapes and thereby reveal not only

certain properties of the surface material but the existence of clay-pan developments or unrelated materials occurring below the surface. Soil color is related to texture and ground water conditions and vegetation is a variable depending upon climate and local influences.

Assembled evidence shows that most soils can be distinguished by characteristic patterns regardless of their geographic distribution. Photographs illustrate the similarity of patterns and test data is presented to permit the evaluation of interpretation.

The use of this information contained in airphotos enables design and construction practices to be established in the early phases of planning peacetime construction or military operations. Grading estimates are made with varying accuracy, depending upon the quality of photography and equipment available but detailed clearing estimates can be made from uncorrected photographs.

ORIENTATION ANALYSIS OF FINE-GRAINED CLASTIC SEDIMENTS.

E. C. DAPPLES AND J. F. ROMINGER.

Using laboratory material, this investigation has been directed toward the extension of methods of orientation analysis to fine-grained clastic sediments to determine their last depositional environment and direction of movement of the depositing agent. Two measurements are made on the projections of grains exposed on the bedding plane: (1) azimuth of elongation, and (2) end position (defined as the position of the larger end of the grain with respect to the smaller end). Grain elongation is measured by constructing two parallel tangents to the grain projection and separated by a minimum distance. End position is determined by construction of the least projection rectangle (least projection tangents to the grain projection and the perpendicular pair of tangents). The end of the grain having the greater area may then be determined by visual inspection.

Following are the results of the experiments:

(1) For sand deposited by running water the grains are elongate parallel to the current direction with their larger end upstream.
(2) For sand deposited by wind action the grains are elongate both parallel to, and perpendicular to the current direction, and have their larger end upstream.
(3) Grains rolled down a slope equal to the angle of repose of dry sand show a random distribution of elongation azimuth.

Should work in the field bear out the laboratory findings, the projection method furnishes a means of determining depositional environments and a quantitative measure of current direction prevalent during the deposition. Such information should prove of importance in determining the sources of petroliferous sediments, in tracing stratigraphic horizons, and in the construction of paleogeographic maps.

THE USE OF ELECTRICAL EARTH RESISTIVITY SURVEYS IN ILLINOIS.[1]

L. E. WORKMAN, CARL A. BAYS, AND MERLYN B. BUHLE.

For nearly fifteen years the electrical earth resistivity method has been used in Illinois to guide test drilling in the search for water-bearing sands and gravels in the glacial drift. During this period many areas in the state have been surveyed and many municipal and industrial water supplies have been located and developed very economically as a result of this work.

[1] Published by permission of the Chief, Illinois State Geological Survey.

Portable instruments are employed by the Illinois State Geological Survey in doing earth resistivity work. The method utilizes a modified Gish-Rooney four electrode system with commutated direct current applied to two steel current electrodes and a potential-drop measurement taken across two copper "potential" electrodes. Spacing of electrodes is by the Wenner system and is closely related to the diameter of the hemisphere of measurement. By increasing electrode spacing, measurements of resistivity to increasing depths are made.

Empirical interpretation methods which are suitable for the geological conditions obtaining in Illinois are applied and all available surface and subsurface information is closely integrated with the resistivity data. Typically the method is used only for location of relatively thick sand or gravel deposits within 250 feet of the surface. Other applications such as the location of highway construction materials have been made.

SCIENTIFIC NOTES AND NEWS

E. S. NORCROSS, JR., has been elected a vice president of Freeport Sulphur Company.

L. KENNETH WILSON, geologist for American Smelting and Refining Company and formerly stationed in Salt Lake City, has been appointed Chief Geologist for the Southwestern Mining Department, 813 Valley National Building, Tucson, Arizona. His residence address is 921 North Second Avenue.

W. E. WRATHER, Director of the United States Geological Survey, has announced recent organizational changes within the Geologic Branch of the Survey, which is headed by Chief Geologist W. H. BRADLEY. This Branch is now subdivided into two Divisions and a Technical Service and Administrative Group. DR. H. M. BANNERMAN has been named Chief of the Division of Economic Geology. During most of the war period he served as Chief of the Section of Non-metallic Minerals. DR. H. S. LADD has been designated Chief of the Division of Areal Geology and Basic Sciences. He was formerly Regional Geologist, in charge of the Rolla, Missouri, office of the Survey. DR. J. W. PEOPLES, Assistant Chief Geologist, has been named head of the Technical and Administrative Group.

A Special Research Staff has been set up within the Geologic Branch, having advisory functions in connection with long-range research planning and Branch policies. This staff includes DRS. D. F. HEWETT, G. F. LOUGHLIN, and W. W. RUBEY. Other geologists are temporarily assigned to this staff as the planning needs dictate.

A new Section of Geologic Information and Reports has been established. DON L. CARROLL, until recently Foreign Editor and Staff Geologist of the *Oil Weekly*, has been designated Chief of the new section.

The following sections now comprise the Division of Economic Geology: Geology of Fuels, H. D. MISER, Chief; Geology of Metalliferous Deposits, CHARLES F. PARK, JR., Chief; Geology of Non-Metalliferous Deposits, JOSIAH BRIDGE, Acting Chief; Foreign Geology, J. V. N. DORR, 2ND, Acting Chief.

Within the Division of Areal Geology and Basic Sciences are included the following sections: Areal Geology, J. T. HACK, Acting Chief; Engineering Geology, E. C. ECKEL, Chief; Chemistry and Physics, W. T. SCHALLER, Chief; Paleontology and Stratigraphy, J. B. REESIDE, JR., Chief; Petrology, C. S. Ross, Chief; Military Geology, E. S. LARSEN, 3RD, Acting Chief; Geophysics, J. R. BALSLEY, Acting Chief.

The Technical Service and Administrative Group includes the following units: Manuscript Review Board, C. H. DANE, Chairman; Geologic Map Editor, E. N. GODDARD; Geologic Cartography, L. B. PUSEY, Chief; Committee on Geologic Names, MISS FRANCES WILLOUGHBY, Secretary; Office of the Chief Clerk, MRS. A. L. BROWN, Chief.

Changes in field assignments have also been announced. A. L. WEISSENBORN, of the Rolla, Missouri office, has been designated as Regional Geologist at Spokane, Washington. ROBERT A. LAURENCE has been made Eastern Regional Geologist, with temporary headquarters at Jefferson City, Tennessee. CHARLES B. HUNT, formerly Chief of the Military Geology Unit, has been designated Regional Geologist at Salt Lake City.

The National Research Council announces that the closing date for applications for the predoctoral fellowships in the natural sciences, under a grant from the Rockefeller Foundation, is to be February 1, 1946. Candidates should write for nomination blanks to the Secretary, Committee on Predoctoral Fellowships, National Research Council, 2101 Constitution Avenue, N.W., Washington 25, D. C.

The American Academy of Arts and Sciences will receive applications for Grants-in-Aid from the Permanent Science Fund. These applications are open for scientific research in various fields. No part of them can be used for doctoral dissertations. Communications should be addressed to JOHN W. M. BUNKER, Chairman, Permanent Science Fund Committee, Massachusetts Institute of Technology, Cambridge, Massachusetts.

INDEX TO VOLUME XL

(NOTE.—In this index the titles of principal papers and headings of departments, as *Reviews*, are in italics.)

Aberdeen, E., abstract by, 586
Abstracts—
Alabama flake graphite in World War II (Pallister and Smith), 92
Alteration and structure in the East Tintic district, Utah (Lovering, et al.), 598
Antimony deposits of Mexico (White), 96
Application of geology to engineering and ground-water problems in Alberta (Allan), 77
Application of oil well surveying instruments and technical services in the mining industry (Kothry), 89
Application of paleoecological method to an early Tertiary coal seam (Wilson), 608
Application of the ternary diagram to analysis and classification of bauxite reserves (Thoenen, et al.), 95
Artificial recharge of artesian limestone at Orlando, Florida (Unklesbay and Cooper), 95, 606
Artificial recharge of glacial sand and gravel with cold filtered river water at Louisville, Kentucky (Guyton), 85, 593
Artificial recharge of ground-water on Long Island, New York (Brashears), 70, 587
Artificial recharge of productive ground-water aquifers in New Jersey (Barksdale and Debuchananne), 78, 586
Asbestos fibre exploration and production forecasts by cave drilling, Jeffrey mine, Asbestos, Quebec (Foster), 83
Beach intelligence-service of the Beach Erosion Board (Edmunds), 590
Chromite deposits of Camaguey Province, Cuba (Guild and Flint), 592
Composite pegmatites of the Franklin-Slyva mica district, North Carolina (Heinrich), 594
Construction problems: Airfields, roads, and general construction (Denny), 588
Contact metamorphic deposits of cassiterite in California (Page), 601
Coral-reef sediments at Morotai, N.E.I. (Aberdeen), 586
Crucible grade graphite (Gwenn), 86
Deviation of diamond drill holes in the Metaline district, Washington (Sampson and Griggs), 94

Abstracts—Continued
Diamond drill sampling calculations, and comparison of methods (Greenhalgh), 85
Diamond drill sampling and estimation of ore at Mascot, Tennessee (Oder and Allen), 92
Diamond drill sludge sampling and appraisal of a weathered ilmenite ore body, Piney River, Virginia (Davidson), 82
Diamond drilling in exploration and development (Moehlman), 91
Effect of radiation on the elastic constants of quartz (Frondel), 84
Engineering applications of aerial reconnaissance (Belcher), 609
Foundation exploration and geologic studies at Cherokee and Douglas Dams, Tennessee (Laurence), 89, 597
General principles of artificial ground-water recharge (Meinzer), 90, 598
General stratigraphy of the east Tennessee zinc deposits (Oder), 92, 600
Geologic interpretation of magnetic exploration on the Mesabi Range, Minnesota (Jones), 88
Geology and fluorspar resources of the Babb fault system, Crittenden and Livingston counties, Kentucky (Hardin), 86
Glass sand and a glass industry in Puerto Rico (Frazier and Meyerhoff), 83
Graphs for obtaining true thickness of a vein or bed (Miller), 91
Gross petrology of coal in relation to exploration of coal reserves by diamond drilling (Schopf and Smith), 604
Guide to geological investigations of dam and reservoir sites (Burwell), 79
Hydrothermal alteration in the Castle Dome copper deposit (Peterson, et al.), 602
Hydrothermal alteration in the San Manuel copper deposit, Arizona (Schwartz), 604
Illinois Geological Survey's activities in war and peace (Leighton), 597
Influence of rock and soil composition on performance of metallic mine detectors (Roberts), 603

Abstracts—Continued
Internal structure of granitic pegmatites (Cameron, et al.), 588
International trade in nonmetallic minerals (Bowles), 78
Introductory statement regarding pollen analysis (Sears), 600
Investigation in petrographic methods of coal analysis (Parks and Cady), 601
Lepidolite—Its occurrences and uses (Clark), 80
Linear analysis of a medium grained granite (Chayes), 588
Lithia pegmatites of the Brown Derby mine, Gunnison County, Colorado (Hanley), 593
Magnesium mineralization in the Currant Creek district, Nevada (Vitaliano), 607
Maximum error in some minerologic computations (Fairbairn and Sheppard), 590
Military geology (Bradley), 78
Military geology unit (Dryden), 589
Military water supply, 603
Modern aspects of geochemistry and their application to economic geology (Stadnichenko), 605
Occurrence and distribution of iron minerals in Pennsylvania fire clays (Leatham), 597
Occurrence of mica-bearing pegmatites in the southeastern states (Griffitts, et al.), 592
Occurrence of tungsten and vanadium in manganese oxide ores and minerals (Fleischer, et al.), 82, 591
Orientation analysis of fine-grained clastic sediments (Dapples and Rominger), 81, 610
Petrographic comparison of Pliocene and Pleistocene volcanic ash from western Kansas (Swineford and Frye), 606
Phosphate rock deposits and industry of the western states (Johnson), 57
Plant microfossils from Illinois Coals (Kosanke), 596
Plant microfossil investigations in western coals—A progress report (Schopf and Cross), 604
Portable differential thermal analysis unit for bauxite exploration (Hendricks, et al.), 594
Post-Paleozoic mineralization in Penn. (Myers), 599
Postwar prospects for fluorspar (Waggaman and Ralston), 95
Preliminary chemical correlation of Chromite with the containing rocks (Thayer), 606
Production of pure and crude phosphates by the Coleman process (Coleman and Teneyck), 80
Quartz crystals in Brazil (Johnston and Butler), 595

Abstracts—Continued
Recent geophysical investigations in the Atlantic Ocean Basin (Ewing and Woollard), 590
Reduction of sulphates in oil-field salt water (Plummer), 602
Searles Lake as a major source of lithium (Gale and Roe), 84
Some problems involved in the interpretation of diamond drill hole sampling and surveying (Collins), 80
Some properties of foundry sands (Ries), 94
Stratigraphic and structural features of the lower Matanuska Valley coal field, Alaska (Payne), 93
Structural control of ore bodies in the Jefferson City, Tennessee area (Brokaw and Jones), 587
Structural control in the eastern belt of the Sweetwater barite district, east Tennessee (Dunlap), 82, 589
Structural and mineralogical characteristics of South Dakota pegmatites (Page), 600
Structural and stratigraphic control of zinc deposits in east Tennessee (Crawford), 81
Structural relations of the upper Mississippi valley zinc-lead district (Heyl and Agnew), 87
Structure of the zinc-lead deposits of northwestern Illinois (Willman), 96, 608
Studies of mineral sulpho-salts: XI-Wittichenite (Klaprothite) (Nuffield), 599
Terrain appreciation: Military appraisal of terrain (Fryxell), 591
Tertiary iron in Triassic collapse breccia (Kelley), 595
Tin and tungsten deposits of French Morocco (Heck), 594
Titaniferous magnetite deposits of the Lake Sanford area, New York (Stephenson), 94
Tracing the course of a flat angle diamond drill hole by electric equipotential lines (Lundberg), 90
Use of electrical earth resistivity surveys in Illinois (Workman, et al.), 610
Work of the U. S. Geological Survey on ground-water supplies for war purposes in the U.S. (McGuinness), 90
X-Ray study of the Tantalum mineral, Simpsonite (Kerr and Holmes), 89
Zinc deposits of the Copper Ridge, Straight Creek, and Powell River areas of east Tennessee (Kent and Rodgers), 88

Abyssal versus the magmatic theory of ore genesis (White), 336–344

Agnew, A. F. with Heyl, A. V., Jr., abstract by, 87, 594

Ahlfeld, F., *The Chicote tungsetn deposit, Bolivia*, 394–407
on germanium, 322
Alaska, coal field (abstract), 93
Alaska, Magnetic exploration of the nickel-copper deposits of Bohemia Basin, southeastern (Walton and Kennedy), 496
Alaskite, 101
Allan, J. A., abstract by, 77
Allanite, 536
Allen, A. T., Jr. with Oder, C. R. L., abstract by, 92
Allen, C. C., and Folinsbee, R. G., discussion of paper by, 148
Anaconda Copper Company, 434
Analyses—
diabase, granophyre, Penna., 533
dolomite, Jackson mine, Bumpass Cove, Tenn., 131
hardrock "porphyry", Little Long Lac, Ont., 511
magnetic concentrates, diabase, 535
manganese content of drill core, Bumpass Cove, Tenn., 132
manganese content, sulphide minerals, Tenn., 131
molybdenum ore, Climax, Colorado, 111
molybdenum ore, Sweetwater, Nev., 112
spectrographic, for beryllium in wallrock, New England, 138
sphalerite, Belgium, 569
spodumene, Preissac-La Motte area, Quebec, 10
tantalite, Preissac-La Motte area, Quebec, 8
water samples, Alexandria, La., 176
Anatase, 30
Andalusite, 304
Andradite, 38
Antimony (abstract), 96
Apatite, 40, 137
Aquifers in Texas, Quantitative studies of some artesian (Guyton and Rose), 193
Aquifers in three areas in Mississippi, Geologic factors affecting the perennial yield of artesian (Brown), 183
Aquifers, Problems of the perennial yield of artesian (Meinzer), 159
Argentite, 352
Arsenopyrite, 400, 558
Artesian aquifers in Texas, Quantitative studies of some (Guyton and Rose), 193
Artesian aquifers in three areas in Mississippi, Geologic factors affecting the perennial yield of (Brown), 183
Artesian aquifers, Problems of the perennial yield of (Meinzer), 159
Artesian water in the coastal area of Georgia and northeastern Florida, The perennial yield of (Cooper and Warren), 263
Asbestos, 121, 444
(abstract), 83
Assimilation, 527
Auger, P. E., and Maurice, O., *Effect of heat treatment on metallic minerals*, 345–352
Axelrod, J. M., et al., abstract by, 82, 591
Azurite, 102

Ball, S. H., on oxidation of molybdenite, 110
Bancroft, J. A., on Quebec pegmatites, 7
Bannerman, H. M., on New England pegmatites, 370
Barite (abstract), 82
Barksdale, H. C., on yield of artesian aquifers, 161
and Debuchananne, G. D., abstract by, 78, 586
et al., on coastal ground-water, 239
Barra Verde mine, Brazil, 46
Barrell, J., on replacement, 421
Bateman, A. M., editorial by, 564
on mineral economics, 447
on Rand district, 336
Bauxite (abstract), 95, 594
Bays, C. A., et al., abstract by, 610
Beach Erosion Board (abstract), 590
Becker, G. F., on replacement 416
Belcher, D. J., abstract by, 609
Benford, J. R., et al., *A polarized light compensator for opaque minerals*, 18–33
Berek, M., on microscopes, 18
Beryl, 2, 9, 524, 565
Beryllium and associated chemical elements in the wallrocks of some New England pegmatites, The presence of (Stoll), 136
Bichan, J. W., on silica, 365
Bichan, W. J., *The cult of the indeterminate. Whither "replacement"?*, 416–424
Billings, K. F., on sillimanite, 303
Billings, M. P., on sillimanite, 302
Biotite, 41, 302, 392
Bismuthinite, 5
Bismutite, 39
Blanchard, R., and Boswell, P. F., on limonite, 104
Bodó mine, Brazil, 48
Bolivia, The Chicote tungsten deposit, (Ahlfeld), 394
Bonito mine, Brazil, 45
Books received, 67, 154, 231, 305, 366, 425, 503, 577
Bornite, 485
Boutwell, J. M., *Economic geology*, 431–448
on replacement, 419
Bowen, N. L., on granophyres, 527
Bowles, O., abstract by, 78
Bradley, W. H., abstract by, 78
Branson, E. B., review of book by, 305
Brashears, M. L., Jr., abstract by, 79, 587
Brazil, Scheelite in northeastern (Johnston and de Vasconcellos), 34
Broderick, T. M., *Geology of the Ropes gold mine, Marquette County, Michigan*, 115–128
Brokaw, A. L., and Jones, C. L., abstract by, 587

Brown, G. F., *Geologic factors affecting the perennial yield of artesian aquifers in three areas in Mississippi*, 183–192
Brown, H. Y. L., on Australia gold, 554
Brown, J. S., on coastal ground-water, 237
Brown, R. H., and Parker, G. G., *Salt water encroachment in limestone at Silver Bluff, Miami, Florida*, 235–262
Bruce, E. L., on Little Long Lac, Ontario, 589
Brucite, 121
Buddington, A. F., and Chapin, T., on Bohemia Basin, Alaska, 499
Buhle, M. A., et al., abstract by, 610
Burwell, E. B., Jr., abstract by, 79
Butler, B. S., and Vanderwilt, J. W., on oxidation of molybdenite, 110
Butler, R. D. with Johnston, W. D., Jr., abstract by, 595

Cadmium, 319
Cady, G. H. with Parks, B. C., abstract by, 601
Cafuca mine, Brazil, 49
Calcite, 40, 109, 487, 495, 524
Calumet and Hecla Copper Company, 437
Cameron, E. N., et al., *Structural and economic characteristics of New England mica deposits*, 369–393
abstract by, 588
Canada, Sphalerites from western (Warren and Thompson), 309
Carbonatization, 122
Carmichael, F., on oxidation, 111
Caron, M. H., and Clevenger, G. H., on silver ores, 490
Cassiterite, 343, 397, 401
(abstract), 601
Cassiterite at Dublin Gulch, Yukon territory, An occurrence of (Thompson), 142
Castlemaine-Bendigo district, Australia, 52
Cerro de Pasco Copper Corporation, 436
Chalcopyrite, 102, 119, 227, 402, 485
Chayes, F., *Petrographic analysis by fragment counting*, 517–525
abstract by, 588
Chicote tungsten deposit, Bolivia (Ahlfeld), 394
Chlorite, 146, 302, 352, 512
Chloritization, 123
Chromium, 312, 444
Chromite (abstract), 592, 606
Church, J. A., on replacement, 416
Clark, J. D., abstract by, 80
Clarke, F. W., on meteorites, 339
Cleavelandite, 388
Cleveland Cliffs Iron Company, 435
Climax, Colorado, oxidation at, 111
Cloos, E., on Safe Harbor, Penna., 528
Coal (abstract), 596, 601, 604
Cobalt, 312, 444
Coheur, P., analyses by, 570
Colorado, oxidation at Climax, 111
Connecticut, pegmatites, 371
Construction problems (abstract), 588
Cook, C. W., on replacement, 373
Cooper, H. H., Jr., and Warren, M. A., *The perennial yield of artesian water in the coastal area of Georgia and northeastern Florida*, 263–282
with Unklesbay, A. G., abstract by, 95, 606
Copper, 337, 496, 565, 568
(abstract), 602, 604
Copper deposits of Bohemia Basin, southeastern Alaska, Magnetic exploration of nickel- (Walton and Kennedy), 496
Cotton, C. A., review of book by, 153
Coulter, W. J., on oxidation, 111
Crawford, J., *Structural and stratigraphic control of zinc deposits in east Tennessee*, 408–415
abstract by, 81
Cross, A. T. with Schopf, J. M., abstract by, 604
Cult of the indeterminate. Whither "replacement"? (Bichan), 416
Curtis, J. S., on replacement, 417

Dale, G. K., et al., abstract by, 95
Dana, E. S., on ferrimolybdite, 102
Dapples, E. C., and Rominger, J. F., abstract by, 81, 610
Darcy, H. C., on artesian aquifers, 159
Davidson, D. M., abstract by, 82
de Almeida, S. C., et al., on Brazil pegmatites, 36
Dean, H. T., on dental health, 181
Debuchananne, G. D. with Barksdale, H. C., abstract by, 78, 586
Denmead, A. K., on Queensland gold, 551
Denny, C. S., abstract by, 588
Deussen, A., and Leonardon, E. G., on electrical well logging, 168
de Moraes, L. J., on Brazil stratigraphy, 35
de Vasconcellos, F. M., with Johnston, W. D., Jr., *Scheelite in northeastern Brazil*, 34–50
Diabases of Pennsylvania, Notes on the derivatives of the Triassic (Tomlinson), 526
Diagrams—
Camp Shelby area, Mississippi, 191
drawdown in aquifer, 278, 279
gold fineness, alluvial workings, 470, 481
gold fineness, lodes, 491
gold fineness, mill, 494
Greywacke lens, Little Long Lac, Ontario, 514
Miami area, Florida, 243
salt water encroachment, Miami, Florida, 255
salt water-fresh water relation, 238
sampling and counting errors, 520
tensional effect in normal faulting, 284
time-temperature curve, 349
variation of counting error, 518
variations in gold fineness, 461
water level flucuations, chlorine content, Miami, Florida, 259
water levels, Brunswick, Geor gia, 272

Diagrams—Continued
water levels, Fernandina, Florida, 273
water levels, Jacksonville, Florida, 274
water levels, Savannah, Georgia, 271
well construction, Alexandria, Louisiana, 171
Diamond drill hole (abstract), 89, 90, 91, 92 94
calculations (abstract), 85
Diamonds, 444
Dickey, P. A., on electrical well logging, 169
Digman, R. E., books received by, 67, 154, 231, 305, 366, 425, 503, 577
reviews by, 153, 230, 575
Dikes, andesite, 102
basic, 298
diabase, 530
"mineral", 120
Discussion and communications—
Minor elements in sphalerites from Belgium (Warren and Thompson), Evrard, 568
Ore minerals of the Laplata Mountains, Colorado, compared with other telluride districts (Galbraith), Shafer, 227
Procupine porphyries (Holmes, et al.), Gustafson, 148
"Solubility" of silica (Kennedy), Hitchen, 361
Doerner, H. A., on molybdenum, 111
Dolomite, 122, 129
Dolomite in Bumpass Cove, Tennessee, Manganese content of the Shady (Rodgers), 129
Donnay, J. D. H., on mineral identification, 353
Drilling, test, for water, 166
Dryden, L., abstract by, 589
Duggan, E. J., on molybdenum, 113
Dunlap, J. C., abstract by, 82, 589
Dunn, J. S., on oxidation, 349
Dupuit, J., on ground-water movement, 159

Eardley-Wilmot, V. L., on molybdenum, 1, 111
Economic geology (Boutwell), 431
Edmunds, C. S., abstract by, 590
Effect of heat treatment on metallic minerals (Auger and Maurice), 345
Ellsworth, H. V., specific gravity tests by, 8
Emmons, S. F., on replacement, 417
Emmons, W. H., on Japan gold, 546
Epidote, 38
Evrard, P., discussion by, 568
Ewing, M., and Woollard, G. P., abstract by, 590

Fabry, R. J. C., analysis by, 10
Fairbairn, H. W., and Sheppard, C. W., abstract by, 590
Faults, Chicote tungsten deposit, 400
Little Long Lac, 510
Morobe Goldfield, 455
Nevada molybdenite deposit, 102
Pachuca silver district, 283
Faults—Continued
Preissac area, 10
zinc area, Tennessee, 408, 412
Fenneman, N. M., on climate, 109
Ferguson, H. G., on gold, 480, 554
Ferrimolybdenite, 102
Fineness of gold, with special reference to the Morobe Goldfield, New Guinea (Fisher), 449, 537
Fishel, V. C., on artesian aquifers, 159
Fisher, M. S., on Morobe Goldfield, 480
Fisher, N. H., *The fineness of gold, with special reference to the Morobe Goldfield, New Guinea*, 449–495, 537–563
Fisk, H. N., on Louisiana stratigraphy, 173
Fissuring in sandstones (Hills and Thomas), 51
Fleischer, M., et al., abstract by, 82, 591
Flint, D. E., abstract by, 592
Florida, Salt water encroachment in limestone at Silver Bluff, Miami, (Brown and Parker), 235
Florida, The perennial yield of artesian water in the coastal area of Georgia and northeastern (Cooper and Warren), 263
Fluorite, 5, 524
Fluorspar (abstract), 86, 95
Fold structure in Australian goldfields, 51
Folinsbee, R. G., with Allen, C. C., discussion of paper by, 148
Foster, G. K., abstract by, 83
Foster, L. V., on microscopes, 18
Fragment counting, Petrographic analysis by (Chayes), 517
Fraser, C., on Hauraki goldfield, 545
Frazier, J. E., and Meyerhoff, H. A., abstract by, 83
Frondel, C., abstract by, 84
on solubility of silica, 361
Frye, J. C., with Swineford, A., abstract by, 606
Fryxell, F. M., abstract by, 591
Fuchs, J., on silica, 364

Galbraith, F. W., discussion of paper by, 227
Gale, W. A., and Roe, L. A., abstract by, 84
Galena, 119, 130, 227, 311, 343, 485, 558, 568
Gallium, 320
Garnet, 5, 36, 137, 304
Gaudin, A. M., on ore determination, 345
Geochemistry (abstract), 605
Geologic factors affecting the perennial yield of artesian aquifers in three areas in Mississippi (Brown), 183
Geological maps—
Barra Verde and Barro Vermelho mines, Brazil, 47
Bodó mine, Brazil, 49
Bohemia Basin, Alaska, 498
Cafuca mine, Brazil, 50
Carrizo sand, Lufkin area, Texas, 208
Chicote massif, Bolivia, 397
Preissac-La Corne area, Quebec, 3
Ropes mine area, Michigan, 120
Sparta sand, Lufkin area Texas, 223

Geological maps—Continued
Travis Peak formation, Camp Hood area, Texas, 215
Water-bearing formations, Texas, 194
Geology, military (abstract), 78
physical (review), 230
Geology of the Ropes gold mine, Marquette County, Michigan (Broderick), 115
Geology to mining in the Pachuca-Real del Monte area, Pachuca silver area, Mexico, Some applications of stuctural (Thornburg), 283
Georgia and northeastern Florida, The perennial yield of artesian water in the coastal area of (Cooper and Warren), 263
Germanium, 322
Gerrie, W., on Quebec pegmatites, 7
Gilbert, C. M., et al., abstract by, 602
Gillingham, W. J., on electrical well logging, 168
Glass (abstract), 83
Gold, 142, 311, 332, 449
Goldich, S. S., et al., abstract by, 594
Gold mine, Marquette County, Michigan, Geology of the Ropes (Broderick), 115
Gold, with special reference to the Morobe Goldfield, New Guinea, The fineness of (Fisher), 449, 537
Gottschalk and Buehler, on oxidation, 110
Granite, 3, 35, 40, 119, 299, 527
(abstract), 588
Graphite (abstract), 86, 93
Graton, L. C., on ore classification, 543
on ore deposition, 229
et al., on Porcupine porphyries, 149
Greene Cananea Copper Company, 435
Greenhalgh, C. W., abstract by, 85
Greenwood, R., on fluorescence, 39
Griffitts, W. R., et al., abstract by, 592
Griggs, A. B., with Sampson, E., abstract by, 94
Grondijs, H. F. and Schouten, C., on thin section preparation, 355
Ground-water (abstract), 77, 78, 79, 90, 586
Ground-water exploration at Alexandria, Louisiana (Maher and Jones), 164
Gruner, J. W., on solubility of silica, 361
Guild, F. N., on ferrimolybdite, 102
Guild, P. W., abstract by, 592
Gustafson, J. F., discussion by, 148
Guyton, W. F., abstract by, 85, 593
on ground-water yield, 206
and Rose, N. A., *Quantitative studies of some artesian aquifers in Texas*, 193–226
on ground-water of Lufkin area, Texas, 224

Hadding, A., on sub-aqueous slides, 57
Haley, D. F., on molybdenite, 111
Hanley, J. B., abstract by, 593
Hanna, M. A., Company, 436
Harder, E. C., on manganese, 129
Hardin, G. C., Jr., abstract by, 86
Hardrock "porphyry" of Little Long Lac (Reid), 509
Hart, L. H., on mineral sequence, 229
Hawley, J. E., on Quebec pegmatites, 7, 14
Heat treatment on metallic minerals, Effect of (Auger and Maurice), 345
Heck, E. T., abstract, 594
Heinrich, E. W., abstract by, 594
et al., abstract by, 592
Helmert, F. R., on earth density, 339
Hendrichs, S. B., et al., abstract by, 594
Herman, J., Laboratories, analysis by, 533, 535
Hess, F. L., on ilsemannite, 103
on pegmatites, 373
Hewett, D. F., on gold, 558
Heyl, A. V., Jr., and Agnew, A. F., abstract by, 87, 594
Hills, E. S., on Melbourne district, 51
and Thomas, D. E., *Fissuring in sandstones*, 51–61
Hilpert, L. S., et al., abstract by, 598
Hitchen, C. S., discussion by, 361
Hobbs, W. H., review of book by, 575
Holmes, A., review of book by, 230
Holmes, R. J., with Kerr, P. F., abstract by, 89
Holmes, T. C., discussion of paper by, 148
Hornblende, 137, 531
Horney, W. R., review by, 305
Horton, F. W., on oxidation of molybdenite, 110
Hotchkiss, W. O., review of book by, 575
Hubbert, M. K., on ground-water, 239
Hudson, W. C., on sillimanite, 298
Hume-Rothery, W., on solid solutions, 321
Hurst, M. E., on Porcupine porphyries, 149

Ilmenite, 30, 514
(abstract), 82
Ilsemannite, 102
Indium, 323
Ingerson, E, and Morey, G. W., on silica, 364
Iron (abstract), 595, 597

Jacob, C. E., on artesian aquifers, 197
Jahns, R. H., et al., abstract by, 588, 592
Jeans, J., on earth development, 337
Johnson, B. L., abstract by, 87
Johnston, W. D., Jr., and Butler, R. D., abstract by, 595
and de Vasconcellos, F. M., *Scheelite in northeastern Brazil*, 34–50
Joly, J., on earth formation, 340
Jones, C. L., with Brokaw, A. L., abstract by, 587
Jones, P. H. with Maher, J. C., *Groundwater exploration at Alexandria, Louisiana*, 164–182
Jones, R. H. B., abstract by, 88

Keele, J., on scheelite, 142
Keith, A., and Sterrett, D. B., on Gaffney-Kings mountain district. 298

Kelley, V. C., abstract by, 595
Kennedy, G. C., *Magnetic exploration of the nickel-copper deposits of Bohemia Basin, southeastern Alaska*, 496–502
The preparation of polished thin sections, 353–360
discussion of paper by, 361
and Walton, M. S., on Bohemia Basin, Alaska, 496
Kent, D. F., and Rodgers, J., abstract by, 88
Kerr, P. F., and Holmes, R. J. abstract by, 89
Kesler, T. L., on manganese, 130
King, P. B., et al., on manganese, 130
Knopf, E. B., and Jonas, A. I., on Safe Harbor, Penna., 528
Knox, H. H., on oxidation, 106
Kosanke, R. M., abstract by, 596
Kothny, G. L., abstract by, 89
Krejci, L., and Ott, E., on silica, 362
Krusch, P., on oxidation of molybdenite, 110
Kyanite, 303

Landes, K. K., on pegmatites, 373
Landslides, at Chicote, Bolivia, 404
Larrabee, D. M., et al., *Structural and economic characteristics of New England mica deposits*, 369–393
Larsen, E. S., and Ross, C. S., on molybdenum, 112
Laurence, R. A., abstract by, 89, 596
Lead, 565
zinc- (abstract), 87, 96
Leatham, E., abstract by, 597
Le Chatelier, H., on silica, 362
Lee, F. W., on electrical well logging, 168
Leighton, M. M., abstract by, 597
Leith, C. K., on education in geology, 439
Furness, J. W., and Lewis, C., on mineral demand, 442
Lund, R. J., and Leith, A., on Michigan stratigraphy, 119
Lenher, V., and Merritt, H. B., on silica, 364
Leonardos, O. H., on scheelite, 34
Lepidolite (abstract), 80
Lewis, J. V., on New Jersey diabase, 534
Limestone, 264, 408, 450, 534
(abstract), 95, 606
Limestone at Silver Bluff, Miami, Florida, Salt water encroachment in (Brown and Parker), 235
Limonite, 102, 146, 401
Lindgren, W., on classification of ore deposits, 127, 538
on oxidation, 106
on replacement, 418
on rock composition, 514
and Ransome, F. L., on Cripple Creek, 544
Lithium (abstract), 84
Locke, A., on gold, 550
Logs, electric, in water well testing, 167
Lohr, E. W., analysis by, 181
and Boreman, J. D., analyses by, 176
Louisiana, Ground-water exploration at Alexandria (Maher and Jones), 164
Lovering, T. S., et al., abstract by, 598
Lundberg, H., abstract by, 90

Mackay, R. A., on gold fineness, 563
Maclaren, J. M., on alluvial desposits, 480
on gold fineness, 547
Mac Laren, M., on gold, 332
Magma, diabase, 526
Magmatic theory of ore genesis, The abyssal versus the (White), 336
Magnesium (abstract), 607
Magnetic exploration (abstract), 88
Magnetic exploration of nickel-copper deposits of Bohemia Basin, southeasterm Alaska (Walton and Kennedy), 496
Magnetite, 302, 534
(abstract), 94
Maher, J. C., and Jones, P. H., *Groundwater exploration at Alexandria, Louisana*, 164–182
Maine, pegmatites, 371
Malachite, 102
Malamphy, M. C., et al., abstract by, 95
Manganese, 323, 444
Manganese content of the Shady dolomite in Bumpass Cove, Tennessee (Rodgers), 129
Map, tectonic (review), 62
Maps—
artesian aquifer yield, Georgia and Florida, 265
Bayou Rapides well field, La., 166
Blister mica mine, Alstead, N. H., 381
Brazil scheelite deposits, 35
Chicote tungsten district, Bolivia, 395
Dublin Gulch in Yukon territory, 143
ground-water withdrawal, Texas, 196
Hall molybdenum deposit, Nevada, 100
Indian molybdenum mine, Quebec, 6
isopach map, United mine, Grafton, N. H. 384
mica districts, Me., N. H., and Conn., 371
mining divisions, British Columbia, 310
Muskeg deposit, Bohemia Basin, 500
Palermo no. 3 mica mine, Groton, N. H., 381
piezometric surface of artesian water, Georgia and Florida, 266, 267, 269
Savannah, Ga., 270
Rice mica pegmatites, Groton, N. H., 387
Ruggles mine, Grafton, N. H., 377
salt water encroachment, Miami, Florida, 248
Silver Bluff area, Florida, 237
Strickland quarry and Cramer mine, Portland, Conn., 378
structure contour, Cramer mine, Portland, Conn., 380
structure contour, Wilcox sand, Camp McCain, Miss., 188

Maps—Continued
test areas, artesian aquifers, Miss., 184
test wells, Silver Bluff area, Florida, 252
Tolgate mica mine, Middletown, Conn., 377
water table, Miami, Florida, 248
water well fields, Houston district, Texas, 202
well locations, Sweeney, Texas, 222
Yakobi Island, southeastern Alaska, 497
Marcasite, 568
Maurice, O. with Auger, P. E., *Effect of heat treatment on metallic minerals*, 345–352
McGuinness, C. L., abstract by, 90
McLean, W. J., et al., *A polarized light compensator for opaque minerals*, 18–33
McNair, A. H., et al., *Structural and economic characteristics of New England mica deposits*, 369–393
abstract by, 588
Meinzer, O. E., *Problems of the perennial yield of artesian aquifers*, 159–163
abstract by, 90, 598
on ground-water supplies, 159, 243
on Nevada rainfall, 104
and Hard, H. A., on artesian aquifers, 160, 196
Mellor, J. W., on silica, 362
Mercury, 312, 565
Meteorites, 339
Mexico, Some applications of structural geology to mining in the Pachuca-Real del Monte area, Pachuca silver area (Thornburg), 283
Meyerhoff, H. A., with Frazier, J. F., abstract by, 83
Mica deposits, Structural and economic characteristics of New England (Cameron, et al.), 369
Michell, W. D., *Oxidation in a molybdenite deposit, Nye County, Nevada*, 99–114
Microcline, 5
Military geology (abstract), 589
Miller, F. S., abstract by, 91
Miller, H. M., abstract by, 600
Mine detector, relation to soil composition (abstract), 603
Mineral dressing (review), 230
Mineralogy, Bolivia tungsten deposits, 400
Brazil scheelite area, 37
Morobe Goldfield, 485
New England pegmatites, 392
Quebec pegmatites, 5
S. Carolina sillimanite area, 302
Tennessee zinc deposits, 412
Minerals, A polarized light compensator for opaque (Turner, et al.), 18
Minerals, Effect of heat treatment on metallic (Auger and Maurice), 345
Minerals, nonmetallic (abstract), 78
Mining in the Pachuca-Real del Monte area, Pachuca silver area. Mexico, Some applications of structural geology to (Thornburg), 283
Mississippi, Geologic factors affecting the perennial yield of artesian aquifers in three areas in (Brown), 183
Missouri, geology of (review), 305
Moehlman, R. S., abstract by, 91
Molybdenite, 10, 99, 119
Molybdenite deposit, Nye County, Nevada, Oxidation in a (Michell), 99
Molybdenite deposits and pegmatites in the Preissac-La Corne area, Abitibi County, Quebec (Norman), 1
Molybdenum, 312
Moore, E. S., and Maynard, J. E., on solubility of silica, 361
Morton, C. C., on Queensland gold, 550
Müllbauer, F., on replacement, 373
Muscovite, 41, 302, 374, 400, 444
Muskat, M., on yield of artesian aquifers, 212, 239
Myers, W. M., abstract by, 599
Mylius, F., and Groschuff, E., on silica, 362
Mylonite, 512

Nelson, R. A., et al., abstract by, 594
Neuschel, S. K., et al., abstract by, 82, 591
Nevada, oxidation in molybdenite deposit in, 99
New England mica deposits, Structural and economic characteristics of (Cameron, et al.), 369
New England pegmatites, The presence of beryllium and associated chemical elements in the wallrocks of some (Stoll), 136
Newhouse, W. H., on replacement, 421
on solid solutions, 141
New Guinea, The fineness of gold, with special reference to the Morobe Goldfield (Fisher), 449, 537
New Hampshire, pegmatites, 371
New international mineral problems, editorial (Bateman), 564
Nickel, 312, 444, 496
Nickel-copper deposits of Bohemia Basin, southeastern Alaska, Magnetic exploration of the (Walton and Kennedy), 496
Norman, G. W. H., *Molybdenite deposits and pegmatites in the Preissac-La Corne area, Abitibi County, Quebec*, 1–17
Notes on the derivatives of the Triassic diabases of Pennsylvania (Tomlinson), 526
Nuffield, E. W., abstract by, 599
Nutting, P. G., on earth formation, 340

Occurrence of cassiterite at Dublin Gulch, Yukon Territory (Thompson), 142
Oden, S., on silica, 364
Oder, C. R. L., abstract by, 92
and Allen, A. T., Jr., abstract by, 92
and Miller, H. W., abstract by, 600
Oliver Iron Mining Company, 435
Olson, J. C., on pegmatites, 372
et al., abstract by, 592
Opaque minerals, A polarized light compensator for (Turner, et al.), 18

Ore genesis, The abyssal vs. the magmatic theory of (White), 336
Orthoclase, 103
Otto, G. H., on micro-sampling, 518
Oxidation in a molybdenite deposit, Nye County, Nevada (Michell), 99

Pachuca silver district, Mexico, Some applications of structural geology to mining in the Pachuca-Real del Monte area (Thornburg), 283
Page, J. J., et al., *Structural and economic characteristics of New England mica deposits*, 369–393
Page, L. R., abstract by, 600, 601
et al., abstract by, 588
Palladium, 312
Pallister, H. D., and Smith, R. W., abstract by, 93
Palmer, C., and Bastin, E. S., on gold, 484, 558
Paragenesis—
Chicote tungsten deposit, Bolivia, 403
discussion, 228
Dublin Gulch, Yukon Territory, 146
Morobe Goldfield, 489
sillimanite area, S. Carolina, 302
Parker, B. H., et al., review of book by, 154
Parker, G. G., with Brown, R. H., *Salt water encroachment in limestone at Silver Bluff, Miami, Florida*, 235–262
and Cooke, C. W., on Florida physiography, 242
Parker, J. M., III, et al., abstract by, 592
Parks, B. C., and Cady, G. H., abstract by, 601
Pascal, P., on silica, 362
Payne, T. G., abstract by, 93
Pegmatites, 35, 320, 369, 530
(abstract), 588
beryl, 2
composite (abstract), 594
lithia (abstract), 593
mica bearing (abstract), 592
South Dakota (abstract), 600
Pegmatites in the Preissac-La Corne area, Abitibi County, Quebec, Molybdenite deposits and (Norman), 1
Pegmatites, The presence of beryllium and associated chemical elements in the wallrocks of some New England (Stoll), 136
Pennsylvania, Cornwall, 422
Pennsylvania, Notes on the derivatives of the Triassic diabases of (Tomlinson), 526
Pentland, A. G., on tin, 147
Pentlandite, 352
Perennial yield of artesian water in the coastal area of Georgia and northeastern Florida (Cooper and Warren), 263
Peridotite, 3, 119
Petar, A. V., on molybdenite, 113
Peterson, N. P., et al., abstract by, 602
Petrographic analysis by fragment counting (Chayes), 517
Petroleum (review), 154
Phelps Dodge Corporation, 436
Phillips, J. A., on Asia gold, 555
Phosphate, rock deposits (abstract), 87
Phosphates (abstract), 80
Photomicrographs—
cassiterite, Dublin Gulch, 144
niccolite, during compensation, 28
pyrrhotite, pentlandite and chalcopyrite, 358
sillimanite schist, South Carolina, 302
Pickands, Mather and Company, 436
Plagioclase, 392
Plans—
adit cross section, Preissac, Quebec, 12
Bulolo and Watut River valleys, Morobe goldfield, 452
Bulolo and Watut Rivers, distribution of gold fineness, 453
Hall molybdenum orebody, 105
Hardrock porphyry, 513
goldbearing creeks, Ramu and Purari rivers, 477
Planets, density of, 339
Plummer, F. B., asbtract by, 602
Polarized light compensator for opaque minerals (Turner, et al.), 18
Pollen analysis (abstract), 605
"Porphyry" of Little Long Lac, The hardrock (Reid), 509
Posepny, F., on replacement, 418
Preissac-La Corne area, Abitibi County, Quebec, Molybdenite deposits and pegmatites in the (Norman), 1
Preparation of polished thin sections (Kennedy), 353
Presence of beryllium and associated chemical elements in the wallrocks of some New England pegmatites (Stoll), 136
Price, P. H., and Lucke, J. B., on structure in limestones, 61
Prindle, L. M., on Alaskan gold, 553
Problems of the perennial yield of artesian aquifers (Meinzer), 159
Proustite, 352
Puckering in Australian goldfields, 55
Pyrite, 5, 102, 119, 130, 146, 227, 352, 400, 485, 495, 512, 558
Pyritization, 123
Pyrolusite, 495
Pyrrhotite, 119, 400

Quantitative studies of some artesian aquifers in Texas (Guyton and Rose), 193
Quartz, 5, 41, 103, 119, 142, 146, 302, 388, 400, 416, 444, 455, 487, 495, 512, 524
(abstract), 84, 595
Quebec, Molybdenite deposits and pegmatites in the Preissac-La Corne area, Abitibi County (Norman), 1
Quick, G. L., et al., abstract by, 602
Quixaba mine, Brazil, 43
Quixeré mine, Brazil, 44

Rabello, C., on scheelite, 34

Ralston, O. C., with Waggaman, W. H., abstract by, 95
Rankama, K., on thin section preparation, 355
Ransome, F. L., on Goldfield, Nevada, 544
Reed, J. C., and Dorr, J. V. N., on Bohemia Basin, Alaska, 496
Reid, J. A., *The hardrock "porphyry" of Little Long Lac*, 509–516
discussion of paper by, 148
Reid, J. H., on Queensland gold, 550
"Replacement"? The cult of the indeterminate (Bichan), 416-
Reviews—
Coasts, waves, and weather for navigators (Stewart), 576
Electronic equipment and accessories (Walker), 576
Fortress islands of the Pacific—Their geography and strategic importance (Hobbs), Digman, 575
Geology of Missouri (Branson), Horney, 305
Handbook of mineral dressing (Taggart), Digman, 230
Migration and accumulation of petroleum and natural gas (Van tuyl, et al.), 154
Minerals of might (Hotchkiss), 575
Principles of physical geology (Holmes), 230
Tectonic map of the United States, 62
Volcanoes as landscape forms (Cotton), Digman, 153
Reynolds, O., on artesian aquifers, 159
Rhodocrosite, 495
Ries, H., abstract by, 94
Roberts, R., asbtract by, 603
Rodgers, J., *Manganese content of the Shady dolomite in Bumpass Cove, Tennessee*, 129–135
with Kent, D. F., abstract by, 88
Roe, L. A. with Gale, W. A., abstract by, 84
Rolff, P. A. M., on Brazil scheelite, 37
Rolker, C. M., on replacement, 417
Rominger, J. F. with Dapples, E. C., abstract by, 81, 610
Rose, N. A., on ground water of Houston area, Texas, 202
with Guyton, W. F., *Quantatitive studies of some artesian aquifers in Texas*, 193–226
and Stuart, W. T., on artesian aquifers, 221
Rutile, 30, 512

Salt water encroachment in limestone at Silver Bluff, Miami, Florida (Brown and Parker), 235
Sampson, E., and Griggs, A. B., abstract by, 94
Sandstones, Fissuring in (Hills and Thomas), 51
Santillán, M., on Pachuca district, 285
Sayre, A. N., abstract by, 603
Scapolite, 39
Schaller, W. T., on ferrimolybdite, 102
on ilsemannite, 103
on pegmatites, 373
Scheelite in northeastern Brazil (Johnston and de Vasconcellos), 34
Schneiderhöhn, H., on oxidation, 105
Schopf, J. M., and Cross, A. T., abstract by, 604
and Smith, H. L., abstract by, 604
Schouten, C., on Simau gold ore, 546
Schrader, F. C., on gold, 558
on molybdenite, 112
Schwartz, G. M., abstract by, 604
Scientific notes and news, 98, 159, 233, 308, 368, 427, 507, 612
Scorza, E. P., on Brazil pegmatites, 36
Sears, P. B., abstract by, 605
Sections—
Bonito mine, Brazil, 45
Camp Hood area, Texas, 216, 217
Camp McCain, Mississippi, 186
Camp Swift area, Texas, 213
Charles Davis mica deposit, Groton, N. H., 386
Chicote Grande, Bolivia, 399
electric logs, Willis, Texas, 203
flow lines, ground water discharging into the sea, 240
furnace, electric, for specimen heating, 346
Hall molybdenum mine, Nevada, 107, 108
Keyes mine, Orange, N. H., 383
Morobe goldfield, 489
Quixaba mine, Brazil, 41
salt water encroachment, Miami, Florida, 247
São Nicoláo mine, Brazil, 40
Sargeant pegmatite, N. H., 376
Saunders mine, Grafton, N. H., 386
silicified limestone with garnet and scheelite, 39
Southland paper mill area, Lufkin, Texas, 209, 224
Strickland-Cramer pegmatite, Portland, Conn., 379
tactite in amphibolite, Brazil, 36
tactite zone on schist contact, 37, 38
test wells, Bayou Rapides field, La., 169, 170
veins, Pachuca district, 288–295
Wadhams-Tucker pegmatite, N. H., 375
well locations and log section, Houston, Texas, 204
zinc deposits, east Tenn., 410
Sericite, 103, 302
Sericitization, 122
Serpentinization, 121
Shafer, P. A., discussion by, 227
Shainin, V. E., et al., *Structural and economic characteristics of New England mica deposits*, 369–393
Shand, S. J., analyses by, 131
Shannon, E. V., on Goose Creek, Va., 529
Sharwood, W. J., on fineness of gold, 482

Sheppard, C. W. with Fairbairn, H. W., abstract by, 590
Scheelite, 34, 119, 142
Shibakov, M., on molybdenite, 113
Short, M. N., on specimen preparation, 348
Siderite, 402
Silicification, 122
Sillimanite in South Carolina (Smith), 298
Silva, H. F., on gold ore assaying, 544
Silver, 115, 119, 312, 332, 487
Simpsonite (abstract), 89
Skeeters, W. W., et al., review of book by, 154
Slichter, C. S., on artesian aquifers, 159
on movement of ground-water, 241
Smith, F. G., on gold, 486
Smith, H. L. with Schopf, J. M., abstract by, 604
Smith, J. F., abstract by, 598
Smith, L. L., Sillimanite in South Carolina, 298–304
Smith, P. G., on gold, 480, 553
Smith, R. W. with Pallister, H. D., abstract by, 93
Society of Economic Geologists, 69, 156, 307, 505, 579
Some applications of structural geology to mining in the Pachuca Real del Monte area, Pachuca silver district, Mexico (Thornburg), 283
Sphalerite, 119, 130, 227, 309, 402, 485, 568
Sphalerites from western Canada (Warren and Thompson), 309
Spodumene, 2, 9
Spurr, J. E., on replacement, 420
Stadnichenko, T., abstract by, 605
Staurolite, 304
Steatitization, 122
Stephenson, L. W., et al., on Mississippi ground-water, 185
Stephenson, R. C., abstract by, 94
Sterrett, D. B., on New England mica deposits, 372
Stewart, G. W., et al., *Structural and economic characteristics of New England mica deposits*, 369–393
Stewart, J. Q., review of book by, 576
Stillwell, F. L., on gold ore, 495
Stoiber, R. E., on sphalerite, 319
Stoll, W. C., *The presence of beryllium and associated chemical elements in the wall-rocks of some New England pegmatites*, 136–141
Stoll, W. M., et al., abstract by, 598
Stose, G. W., et al., on manganese, 129
and Schrader, F. C., on manganese, 129
Stratigraphic control of zinc deposits in east Tennessee, Structural and (Crawford), 408
Stratigraphy—
Bolivia tungsten area, 396
Brazil scheelite area, 37
Tennessee zinc deposits, 412
Stringham, B. F., et al., abstract by, 598
Structural and economic characteristics of New England mica deposits (Cameron, et al.), 369
Structural and stratigraphic control of zinc deposits in east Tennessee (Crawford), 408
Structural control of ore body, 126
Structural geology to mining in the Pachuca-Real del Monte area, Pachuca silver area, Mexico, Some applications of (Thornburg), 283
Structure—
Little Long Lac, Ontario, 509, 513
Morobe goldfield, New Guinea, 455
New England pegmatites, 392
zinc deposits, east Tenn., 408
Stuckey, J. L., on kyanite, 303
Swineford, A., and Frye, J. C., abstract by, 606

Tables—
analyses
see analyses
analyses in micro-sampling, 521
coefficients of transmissibility of limestone aquifer, 281
fineness of gold, Homestake, 556
fineness of gold, Morobe district, 458, 539
formation heats of elements, 338
formation heats of oxides and carbides, 340
gold and silver content, Edie lodes, Morobe district, 490
gold production of the Morobe district, 458, 539
log and analysis, drill core, Bumpass Cove Tenn., 132
measurement on ilmenite, 30
measurements on uniaxial minerals, 29
mineral distribution in diabase, 532
minor elements in pegmatite wallrock, New England, 139
minor elements in western Canadian sphalerites, 314–318, 327, 330, 331
New England pegmatites and literature, 137
precious metal mines, British Columbia, 333
production, precious metals, district north of Ishpeming, Michigan, 118
production, Ropes mine, 124
productivity of N. H. and Conn. mica deposits, 390
records, test drilling, Alexandria, La., 175
salt water encroachment, Miami, Florida, 253
spectrographic analysis, diabase, 532
spectrographic lines used in determinations, 313
water withdrawal, Texas, 195
Tactite, quartz-epidote, Brazil, 38
Taggart, A. F., review of book by, 230
Tantalite, 2, 8

Tennessee, Structural and stratigraphic control of zinc deposits in east (Crawford), 408
Terrones, A., et al., abstract by, 598
Tetrahedrite, 119, 124, 227, 311, 495
Texas, Quantitative studies of some artesian aquifers in (Guyton and Rose), 193
Thallium, 312
Thayer, T. P., abstract by, 606
Theim, G., on ground-water movement, 160
Theis, C. V., on ground-water movement, 161, 184, 196, 277
Thin sections, The preparation of polished (Kennedy), 353
Thoenen, J. R., et al., abstract by, 95
Thomas, D. E. with Hills, E. S., *Fissuring in sandstones*, 51–61
Thompson, D. G., on yield of artesian aquifers, 161
Thompson, R. M., *An occurrance of cassiterite at Dublin Gulch, Yukon territory*, 142–147
with Warren, H. V., *Sphalerites from western Canada*, 309–335
discussion of paper by, 568
Thorium, 312
Thornburg, C. L., *Some applications of structural geology to mining in the Pachuca-Real del Monte area, Pachuca silver district, Mexico*, 283–291
Thraill, J. G., on sphalerite, 319
Tin, 311, 444, 565
(abstract), 594
Titanium, 326
Tolman, C. F., on artesian aquifers, 159
and Polland, J. F., on artesian aquifers, 161
and Rogers, A. F., on mineral identification, 353
Tomlinson, W. H., *Notes on the derivatives of the Triassic diabases of Pennsylvania*, 526–536
Tourmaline, 5, 119, 137, 142, 146, 304, 397, 400
Triassic diabases of Pennsylvania, Notes on the derivatives of the (Tomlinson), 526
Tungsten, 142, 394, 565
(abstract), 82, 594
solutions, 40
Tungsten deposit, Bolivia, The Chicote (Ahlfeld), 394
Turner, A. F., et al., *A polarized light compensator for opaque minerals*, 18–33

Umpleby, J. B., on replacement, 422
Unklesbay, A. G., and Cooper, H. H., Jr., abstract by, 95, 606
Utah, Iron Springs, 422

Vanadium, 326, 565
(abstract), 82
van der Veen, R. W., on mineral identification, 353
Vanderwilt, J. W., on molybdenite, 112
Van Tuyl, F. M., et al., review of book by, 154
Veins—
asbestos, 116
cassiterite, 403
diabase, 531
gold, 450, 510
in Shady dolomite, 130
molybdenum, 1
quartz, 38, 103, 119, 298, 416
scheelite, 118
silver, 283
tungsten, 394, 398
Vitaliano, C. J., abstract by, 607
Volcanoes, 341
(review), 153

Wadsworth, A. H., et al., abstract by, 598
Waggaman, W. H., and Ralston, O. C., abstract by, 95
Wagner, H. C., et al., abstract by, 598
Walker, R. C., review of book by, 576
Walton, M. S., Jr., *Magnetic exploration of the nickel-copper deposits of Bohemia Basin, southeastern Alaska*, 496–502
War and postwar changes in this journal, editorial (Bateman), 566
Warren, H. V., and Thompson, R. M., *Sphalerites from western Canada*, 309–335
discussion of paper by, 568
Warren, M. A. with Cooper, H. H., Jr., *The perennial yield of artesian water in the coastal area of Georgia and northeastern Florida*, 263–282
Washington, H. S., on earth composition, 339
Water supply, military (abstract), 603
Weiser, H. B., on solubility of silica, 361
Wentworth, C. K., on coastal ground-water, 239
Wenzel, L. K., on yield of artesian aquifers, 160, 198, 275
and Sand, H. H., on Dakota sandstone, 161
White, C. H., *The abyssal versus the magmatic theory of ore genesis*, 336–344
on ore genesis, 337
White, D. E., abstract by, 96
White, T. M., on gold ore treatment, 544
Whitman, A. R., on Porcupine porphyries, 150
Willman, H. B., abstract by, 96, 608
Wilson, L. R., abstract by, 608
Winchell, A., on earth formation, 340
on gold fineness, 482
Wisser, E., on Pachuca district, 285
Wolframite, 394, 401
Wood, R. W., on optics, 20
Woollard, G. P. with Ewing, M., abstract by, 590
Workman, L. E., et al., abstract by, 610
Wright, C. W., on replacement, 423
Wyart, M. J., on silica, 364
Wyckoff, R. W. G., on cadmium, 319

Yagoda, H., abstract by, 97, 609
Yukon territory, An occurrence of cassiterite at Dublin Gulch (Thompson), 142

Zinc, deposits, (abstract), 81, 88, 92
lead (abstract), 87, 96
Zinc deposits in east Tennessee, Structural and stratigraphic control of (Crawford), 408
Zoning, in Bald Hill batholith, 558
in Bolivia tungsten deposits, 394
in pegmatites, 372

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